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PROCEEDINGS

of the

Indiana Academy *of* Science

Founded December 29, 1885

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Volume 73

1963

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RICHARD A. LAUBENGAYER, Editor
Wabash College
Crawfordsville, Indiana

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Spring Meeting
May 10-11
Pokagon State Park

Fall Meeting
October 10-12
GOSHEN COLLEGE

Published at Indianapolis, Indiana
1964

1. The permanent address of the Academy is the Indiana State Library, 140 N. Senate Ave., Indianapolis 4, Indiana.

2. **Instructions for Authors** appear at end of this volume, P. 277.

3. **Exchanges.** Items sent in exchange for the Proceedings and correspondence concerning exchange arrangements should be addressed:
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4. **Proceedings** may be purchased through the State Library at $5.00 per volume.

5. **Reprints of technical papers** can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

6. The Constitution and By-Laws reprinted from v. 62 and the Membership List reprinted from v. 67, are available to members upon application to the Secretary. Necrologies reprinted from the various volumes can be supplied relatives and friends of deceased members by the Secretary.

7. Officers whose names and addresses are not known to correspondents may be addressed care the State Library. The address of the editor of the present volume is Biology Department, Wabash College, Crawfordsville, Ind.

Papers published in the Proceedings of the Indiana Academy of Science are abstracted or indexed in appropriate services listed here:

Annotated Bibliography of Economic Geology

Bibliography of Agriculture

Bibliography of North American Geology

Biological Abstracts

Chemical Abstracts

Chemisches Zentralblatt

Current Geographical Publications

Geological Abstracts

Mathematics Reviews

Metallurgical Abstracts

Psychological Abstracts

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The Torrey Bulletin

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Officers and Committees

OFFICERS FOR 1963

President.....Howard H. Michaud, Purdue University
Vice President.....Edward L. Haenisch, Wabash College
Secretary.....William W. Bloom, Valparaiso University
Treasurer.....Kermit H. Carlson, Valparaiso University
Editor.....Richard A. Laubengayer, Wabash College
Press Secretary.....Frank N. Young, Indiana University

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Bacteriology.....Richard Smith, Miles Ames Research Lab., Elkhart
Botany.....J. H. Maysilles, Hanover College
Chemistry.....Keith White, Hanover College
Entomology.....George E. Marshall, Experiment. Hort. Orchard, Mitchell
Geology and Geography.....William Kowitz, Valparaiso University
History of Science.....A. T. Guard, Purdue University
Mathematics.....Ernst Snapper, Indiana University
Physics.....Paul Bender, Goshen College
Plant Taxonomy.....Joseph Hennen, Indiana State College
Psychology.....William Martin, Purdue University
Soil Science.....Gerald E. Wilcox, Purdue University
Zoology.....Carl Krekeler, Valparaiso University

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(Past Presidents, Current Officers, Divisional Chairmen, Committee Chairmen)

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Cleland, R. F.
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Weatherwax, P.
Weaver, H. D.
Welch, W. H.
Young, F. N.
Youse, H. R.
Yuncker, T. G.

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(Consisting of President, Secretary, Treasurer, Editor; Chairmen of the Junior Academy, Library, Program, and Relation of Academy to State.) Howard H. Michaud, William W. Bloom, Kermit H. Carlson, Richard A. Laubengayer, Tom Overmire, Nelle M. Coats, Henry D. Weaver, Jr., William A. Daily.

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Trustees of the Academy Foundation: Chairman, Frank J. Welcher, Indiana University, Adult Ed. Center, Indianapolis (appointed to fill the unexpired term of Ward Rice—term expires 1964); William A. Daily (1965).

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Necrologist: W. E. Edington, DePauw University.

Program: Chairman, Glen R. Miller, Goshen College; Paul Bender, C. Franklin Bishop, Henry D. Weaver, Jr., Lester G. Zimmerman.

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Resolutions: Chairman, Howard Youse, DePauw University; Shelby Gerking, Indiana University; Lawrence Baldinger, University of Notre Dame.

Special Constitution Revision Committee: Chairman, Paul Weatherwax, Indiana University and Franklin College; R. H. Cooper, Ball State College; Ray T. Everly, Purdue University; William A. Daily, Eli Lilly and Company.

Youth Activities Committee: Chairman, Paul Klinge, Indiana University; Harry G. Day, K. H. Carlson, Otto Behrens, Robert Brooker, R. H. Cooper, Sears Crowell, Herschel Dassel, Willis Johnson, A. C. Koester, R. W. Lefler, Howard Michaud, Woodrow Pemberton, Lawrence Poorman, William Smith, Ervin Steincamp, L. A. Willig, Ruth Wimmer, Thomas Overmire, Karl Kaufman, Mrs. Elizabeth Crider.

Indiana Science Fairs: Director, L. A. Willig, Tri-State College; Regional Directors: Vincent Flannery, A. C. Koester, R. E. Niswander, W. A. Threlkeld, R. K. Lewton, Charles Hess, W. J. Brett, G. E. Doeden, R. M. Brooker, Paul Klinge, Brian Hill, D. H. Follett.

Indiana Science Talent Search: Director, Sears Crowell, Indiana University; L. H. Baldinger, J. M. Egar, Harold Garner, Vergil Heniser, Morris Taylor.

Indiana Junior Academy of Science: State Sponsor, Thomas Overmire, Ball State College; Council: Ervin Steincamp, Sister Suzanne, V. C. Cripe, Don Winslow, Helen Reed.

Indiana High School and College Committee on Mathematics: Chairman, J. C. Polley, Wabash College; G. N. Wollan, G. D. Vannatta.

Visiting Scientists: Chairman, William G. Kessel, Indiana State College; K. H. Carlson, R. H. Cooper, Elizabeth Crider, E. Litweiler.

SPRING MEETING

Pokagon State Park

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

May 10, 1963

The meeting was called to order by the president, Dr. Howard H. Michaud at 4:45 P.M. Sixteen members of the committee were in attendance.

The treasurer, Dr. Kermit H. Carlson, submitted his report as of April 30, 1963. A summary of his report is as follows:

State Academy Accounts

Balance as of Jan. 1, 1963	$8,136.57	
Receipts to April 30, 1963	4,234.73	12,371.30
Disbursements to April 30, 1963		6,749.10
Balance in State Academy Accounts		5,622.20

National Science Foundation Accounts

Balance as of Jan. 1, 1963	$12,566.58
Disbursements	8,395.89
Balance as of April 30, 1963	4,170.69

Dr. Carlson reported on the costs of sending state winners and sponsors to the National Science Fair and that indications were that the income will be sufficient to meet these expenses. The treasurer's report was approved as read.

The editor, Dr. Richard A. Laubengayer was unable to attend but submitted the following report: 1800 copies of the Proceedings had been ordered, 1200 to be hard bound and 600 paper bound. The galley is in preparation and should be in the hands of contributors before the end of the month. The editor also submitted recommendations for meeting the cost of the publication of the Proceedings. Discussion of the recommendations was postponed to new business.

The press secretary, Dr. Frank N. Young, reported that the newspaper, radio, television, and wire services coverage of the fall meeting of 1962 had been good and that he would attempt to get as much coverage as possible for the fall meeting in 1963. He emphasized the necessity of his getting abstracts as soon as possible in the fall in order to secure the best news coverage.

Dr. Henry D. Weaver, as acting program chairman, reported everything in order for the meetings later in the day and for the Saturday field trips. He reported that the call for papers would be made early in August and that the final mailing of the programs would occur about October 1. September 7 was set as the deadline for receiving materials to be included in the printed programs.

In the absence of the membership chairman the secretary presented the fourteen applicants for membership in the Senior Academy and the one club application for membership in the Junior Academy.

The librarian, Miss Nelle Coats, reported that the Indiana State Library had forwarded copies of the Proceedings as issued to members of the Academy and that the Academy Library distributed copies of the latest volume to institutions on the exchange list in the United States and foreign countries. She also reported the action of the Budget Committee requesting her to make an inventory of the copies of the Proceedings on hand as well as the 50 Year Index and Indiana Scientists and to make available to the membership excess copies on a free, first-come basis.

Dr. Ray T. Everly, chairman of the Fellows Committee, reported on the study and recommendations made by his committee. He reported that there were one hundred eighty-eight members of the Academy who were Fellows and that certificates were being prepared for them.

Dr. Robert Cooper, chairman of the Invitations Committee, reported on the possible future host for the meetings as Wabash in 1964, Ball State Teachers College in 1965, and Notre Dame and Indiana Technical College in the near future. A motion carried to the effect that the Invitations Committee be guided by a suggestion that every third meeting be held somewhere near the center of the state.

The Research Committee reported that there were $600.00 in the Research Grants Fund on Jan. 1, 1962; $610 had been received from the A.A.A.S. and $300.00 from the Academy Foundation, for a total of $1510.00. During this time, Dr. Arthur Smucker received a grant of $160.00 and Dr. Winona Welch received a grant of $150.00 for a total of $310.00 in grants. The balance in this fund available for research grants is now $1200.00.

After some discussion of proposals made by the Editor concerning policies for the publication of the Proceedings, the following motion was approved by the Executive Committee:

No author may submit manuscripts totaling more than ten (10) doublespaced typewritten pages, including literature cited, and no more than two illustrations (tables, photographs, etc.) for a total of not more than twelve (12) pages of manuscripts without paying the addition costs of publication.

If any individuals are invited to submit manuscripts, it must be understood that they must be members of the Academy if they wish to have their manuscripts published in full. Also, their manuscripts would be subjected to the above rules. The contents of their manuscripts must fall within the range of material that is usually acceptable for publication in the Proceedings.

A motion carried to approve an allowance of not more than $30.00 for the preparation and mailing of Fellows Certificates.

The meeting of the executive committee adjourned at 6:20 P.M.

WILLIAM W. BLOOM, Secretary

Approved October 10, 1963

SPRING MEETING

POKAGON STATE PARK

May 10, 1963

Following the dinner served in the main dining room of the Inn at Pokagon State Park, the formal business session of the Spring Meeting of the Academy was called to order in the lobby of the Inn by President Howard H. Michaud. The president then introduced the officers and special guests to the members present.

The proposed amendments to the Constitution and By-Laws which had been read for the first time at the Fall Meeting in 1962 was read for the second time. The proposed amendments were as follows:

In the second sentence of Article III of the constitution, the word *President-Elect* be substituted for *Vice-President*, and that the words *Membership Secretary* be added after the word *Secretary*. The sentence as amended would then read: "They (the officers) shall consist of a President, a President-Elect, Divisional Chairmen, a Secretary, a Membership Secretary, a Press Secretary, an Editor, and a Treasurer."

Section 2 of Article I of the By-Laws be replaced by the following: "Section 2. President-Elect. The President-Elect shall assume the office of President immediately following the last business session of the fall meeting of the Academy in the year in which he has served as President-Elect. During his term as President-Elect, he shall discharge all the duties of the chief executive officer in the absence of the President. He shall familiarize himself with all the operations of the Academy and prepare lists of committee appointments prior to assuming the office of President."

The following be adopted as Section 5 of Article I of the By-Laws, and that the numbering of the present sections 5 through 7 be changed to 6 through 8: "Section 5. Membership Secretary. The Membership Secretary shall assume all duties concerned with the maintenance of membership list and shall be prepared at all times to provide officers, committee chairmen, and sectional chairmen with lists necessary to their operations. He shall develop such forms as are necessary for keeping proper records of membership. He shall, at regular intervals, secure from the Secretary and the Treasurer the information necessary for maintaining these lists."

Section (m) of Article II of the By-Laws, which has been amended since its original adoption, be rewritten to read as follows: "Section (m). Committee on Fellows. Membership of the Committee on Fellows shall be limited to one representative from each division of the membership of the Academy. The term of office shall be three years. Beginning in 1963 with the divisions listed in alphabetical order, one-third of the members shall be appointed to serve for three years, one-third for two years, and the remaining group for one year. In subsequent years, these division

representatives shall be replaced when their terms expire with others appointed to serve for three years. Representatives of new divisions which shall be organized in the future shall be added to the group with the smallest number of appointees, and their terms of office shall expire with the terms of the others of that group. The chairman of the committee shall have had at least one year of service on the committee."

The following new section be added to Article II of the By-Laws: Section (n). Committee on Constitution and By-Laws. The duties of this committee shall be to justify all executive actions, to keep the constitution and By-Laws up-to-date, and to give advice and assistance in the preparation of proposed amendments. The committee shall consist of three members in rotating order, the chairman serving during the last year of his term. The chairman of the committee shall be a member ex-officio of the Council of the Academy.

The proposed amendments were approved and become a part of the Constitution and By-Laws of the Academy.

Fourteen applications for membership in the Senior Academy and one club application for membership in the Junior Academy were approved.

The program for the evening was then presented. It consisted of photographic sketches from field and laboratory prepared by Dr. S. W. Witmer, professor emeritus in Biological Science at Goshen College and represented kodochrome slides taken over a wide range of time and geographical area. Dr. Witmer himself was unable to make the presentation due to a very recent hospitalization and surgery, and Dr. Bishop of the Goshen faculty read the prepared script.

A motion carried expressing special thanks to the management of the Inn, to Dr. Witmer and Dr. Bishop for their contributions to the program.

The members present also expressed their special concern for Dr. Witmer and extended him greetings and wishes for a speedy recovery.

Dr. Weaver announced the time and meeting places for the field trips to be held on Saturday morning, following which the meeting was adjourned.

WILLIAM W. BLOOM, Secretary

Approved October 10, 1963

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

GOSHEN COLLEGE, Goshen, Indiana

October 10, 1963

The fall meeting of the Executive Committee was called to order by President Howard H. Michaud at 7:40 P.M. Twenty-four members were present.

The minutes of the Spring meeting of the Executive Committee and the General Session of the Academy held on May 10 at Pokagon State Park were read and approved.

Treasurer—Dr. Kermit Carlson: A summary of the financial report as of Sept. 30 is as follows:

Jan. 1 balance plus receipts in State Accounts as of Sept. 30, 1963—$20,660.66; disbursements $14,474.77; present balance $6,185.89.

Jan. 1 balance plus receipts in NSF funds as of Sept. 30, 1963—$13,026.58; disbursements—$11,522.81; balance as of Sept. 30, 1963—$1,503.77.

FINANCIAL REPORT OF THE INDIANA ACADEMY OF SCIENCE

January 1, 1963 thru December 31, 1963

Account Name	*Balance Jan. 1 Plus Receipts*	*Disbursed*	*Balance*
1. Indiana Academy Science (budget) ...	8,513.04	6,243.55	2,269.49
2. Junior Academy	32.16	23.70	8.46
3. Academy Funds Designated for Research	1,500.00	300.00	1,200.00
4. J. S. Wright Memorial Library and Lilly Endowment Fund	768.06	22.25	745.81
5. Science Fair	8,433.15	8,241.53	191.62
6. Science Talent Search	2,324.42	1,251.09	1,073.33
Total in State Accounts	21,570.83	16,082.12	5,488.71
National Science Foundation General Fund Cash			
G 22464	12,566.58	11,676.70	889.88
Tax Held in Trust	13.30		13.30
G 12412	3,180.71		
G 1846	1,460.00	1,950.06	2,690.65
Total NSF	17,220.59	13,626.76	3,593.83
Total State and NSF	38,791.42	29,708.88	9,082.54

Bank Balances: Farmers State Bank 4,988.95
First Federal Savings and Loan Assn. 4,093.59

9,082.54 Balance

Kermit H. Carlson, Treasurer
December 31, 1963

We have examined these accounts this date, Jan. 18, 1964, and have found them to be accurate and in order.

Auditing Committee
R. J. Hanson
Clarence Dineen

Editor—Dr. Richard A. Laubengayer: Dr. Laubengayer reported that 1,200 hard bound and 600 paper bound copies of Volume 72 has been delivered and were ready for distribution. The reprints are already in the mails and should be in the hands of the contributors.

Press secretary—Dr. Frank N. Young: Dr. Young reported that notices of the spring and fall meetings were sent to newspapers, wire services, and radio and television stations over the state. The news bureaus of all institutions with members participating in the Academy programs were informed and requested to release local publicity.

The Trustees of the Academy Research Endowment Fund: W. A. Daily, chairman, protem reported as of Oct. 1, 1962, a beginning balance of $1,017.81; total receipts Oct. 1, 1962 to Sept. 12, 1963—$676.98; disbursements were $846.01 leaving an ending balance of $848.78. The total carrying value of the fund was $15,559.46.

The Research Grant Committee: Two grants were made during the past year as follows: Dr. Winona Welch—$150; Prof. J. O. Whitaker, $150. Approximately $1000 is available for grants.

Youth Activities Committee—Paul Klinge, Chairman:

A. Science Fairs—The State Director, Dr. L. A. Willig, has resigned after unusually outstanding service in this capacity. He has been largely responsible for the fund raising involved in this program which is a large task. His responsibilities also include the state organization, publicity, posters, meetings, National Science Fair trip, etc.

He has announced his resignation. The Academy is certainly deeply in debt for his unselfish and untiring efforts which have been so productive.

Winners from all 12 Regionals, and their teachers, participated in the National Science Fair at Albuquerque, the first week in May, 1963.

President Michaud has appointed Dean Karl Kaufman, College of Pharmacy, Butler University, Indianapolis, to the post of State Director.

B. Junior Academy of Science—Professor Thomas Overmire, Ball State Teachers College, Muncie, has been appointed as State Sponsor to replace Professor Michaud. Mr. Erwin Steinkamp, New Albany High School, New Albany, replaces Mr. Robert Weber on the Council.

C. Science Talent Search—Professor Virgil Heniser, Coordinator for School Science, Indiana University, Bloomington, has been appointed Director to replace Professor Sears Crowell. Professor Morris Taylor, Department of Physics, Purdue University, has been appointed to replace Professor Henry, Wabash College, on the Committee.

The Junior Scientists Assembly was held at the Indiana University Medical Center in Indianapolis in March, 1963. Tri Kappa sorority continues to provide the financial support for this program.

The budget remains the single most formidable problem in the operation of these programs. It still remains an unsolved problem if hand-to-mouth financing is ever to be eliminated.

Mr. Robert Kent, NDEA Science Consultant, Indiana State Department of Public Instruction, in consultation with President Michaud and Professor Klinge, has proposed to the U. S. Office of Education a modest grant for the support of the Youth Activities Committee. This is not intended to eliminate the budgetary problems of the separate programs, however.

The Committee Chairman, directed by the Committee, has prepared informational material for the use of school administrators and teachers for all state science activities.

Auditing Committee: Dr. Carlson reported that the Auditing Committee had audited and approved the financial records as of Dec. 21, 1962.

Biological Survey Committee, C. A. Markle, Chairman:

Publications of 1962-1963

Dealing with the Flora and Fauna of Indiana

Algae:

1. Daily, W. A., 1963. Notes on Algae found in Indiana. Proc. Inc. Acad. Sci., Vol. **72**:
2. Hall, C. R., 1963. Notes on Indiana Algae, Primarily from Putnam County. Proc. Inc. Acad. Sci., Vol. **72**:

Bryophyta:

1. Lantz, Larry A., 1963. Acrogynous *Jungermanniales;* A Taxonomic Treatment of the species occurring in Indiana. Submitted as a thesis for A.M. degree, DePauw, June 1963. In DePauw Library.
2. Welch, Winona H., 1963. Bryophytes of Cabin Creek Raised Bog. Proc. Ind. Acad. Sci., Vol. **72**: 105-107.
3. ————, 1963. *Fontinalaceae.* (Ind. species are included.) North American Flora, Series 2, Part 3: 1-51.
4. ————, 1963. Studies in Indiana Bryophytes XIII. Proc. Ind. Acad. Sci., Vol. **72**: 270-278.

Insecta:

1. Siverly, R. E., 1962. Occurrence of *Culex territans* Walker in Indiana. Proc. Ind. Acad. Sci., Vol. **71**: 115.

Aves:

1. Many Contributors, 1962-1963. Regional and Field Reports. Indiana Audubon Quarterly Vol. 40-41.

Work in Progress or Completed, but not yet Published,

Dealing with the Flora and Fauna of Indiana

Vascular Plants

1. Jackson, M. T. and A. A. Lindsey. Effects of microclimates on the flowering phenology of spring flowering plants in central Indiana.
2. Markle, Carrolle A., Norman Richardson and Mary Beth Schnur. Contributions to the Flora of Wayne County, Indiana.
3. Petty, R. O. and D. Harwood. Rush Woods, a Lowland Extension of the Beech-Maple Climax, Montgomery Co., Indiana. Proc. Ind. Acad. Sci., Vol. 73.
4. Petty, R. and E. Williams. Cycling of Radioisotopes in a central mesophytic forest, Allee Memorial Woods, Parke Co., Indiana. Publication: Special reports AEC. Proc. Ind. Acad. Sci., Vol. **73**.
5. Schmelz, Damien and A. A. Lindsey. Phytosociological comparisons among old-growth forests of Indiana.

	6.	Witmer, S. W. A New Station for *Butomus umbellatus* L. in Indiana.
Annelida:	1.	Joyner, James J. Earthworms of Indiana.
Crustacea:	1.	Cole, Ronald. Crayfish of Middle-Eastern Indiana.
	2.	Gammon, James. Distribution of Crayfish in Streams of Putnam County, Indiana and vicinity.
	3.	Wise, Charles D. Ostracods of Indiana.
Insecta and Arachnida:	1.	Siverly, R. E. Taxonomic and Ecological Studies of Mosquitoes of Indiana.
	2.	Ward, Gertrude L. Spiders of Indiana.
	3.	Ward, Gertrude L. and Jean Allen, Terrence Marsh, Lee Reynolds, Nancy Bourke. Insects of Whitewater Valley, Indiana.
Pisces:	1.	Cope, James B. and Edward Gardella. Collection and Identification of Fish of Whitewater Valley.
	2.	Gammon, James R. Distribution of fishes in the streams of Putnam County, Indiana and vicinity.
	3.	Proffitt, Max A. Collection and classification of the pisces in region of Terre Haute, Indiana.
Aves:	1.	Cooper, Robert H. Further notes on the Occurrence of the Whistling Swan (*Cygnus columbianus* L.) in Delaware County, Indiana. Proc. Ind. Acad. Sci. Vol. 73.
	2.	Cope, James B. Bird Migration Studies.
	3.	Cope, James B. and William Buskirk. Birds of Indiana.
	4.	Indiana Audubon Society Members; Several Contributors. Work and field notes on birds of Indiana. To be published in Indiana Audubon Quarterly.
Mammalia:	1.	Cope, James B., Stephen Humphrey and John Whitesell. Bat Migrations and other studies on bats in Indiana.
	2.	Whitaker, John O. Collections of the mammals in region of Terre Haute, Indiana.
Miscellaneous Plant and Animal Groups:	1.	Klotz, John W. "Of Bogs and Logs." Biweekly in the Sunday Magazine section of the Ft. Wayne Journal Gazette. Deals with biological phenomena with special reference to northeastern Indiana.
	2.	Authors Various. ACRES BULLETIN (Quarterly). Short articles on biological phenomena of interest to members.

Fellows Committee—Dr. Ray T. Everly, reporting for the Fellows committee, recommended the following for election to the status of fellow in the Academy: James Cope, Richard Louis Conklin, George B. Cummins, Robert Ledyard Henry, R. Emerson Niswander, and Howard Ray Youse. The recommendations were approved.

He also reported that certificates were prepared and mailed to 188 Fellows of the Academy who had been elected prior to 1962.

A number of recommendations concerning the election of fellows was referred to the Constitution revision committee for consideration.

Invitations Committee—Dr. Robert Cooper, chairman: Dr. Cooper reported that Indiana Central College had invited the Academy to hold its 1964 fall meeting at Indiana Central College. Notre Dame had previously expressed interest in serving as host in the near future. The executive agreed to accept the invitation of Indiana Central for 1964 and that of Notre Dame for 1965 if a formal invitation is received.

Library Committee—Nelle Coats, chairman, submitted the following report for the John Shepard Wright Memorial Library:

For use primarily as display material the following items were purchased on the John Shepard Wright Fund, the selection honoring one of Mrs. Wright's interests: British Museum, Eggs of British Birds, 5 volumes; Poynting, Eggs of British Birds; Smythies, Birds of Borneo; Smythies, Birds of Burma; and Tweedie, Malayan Birds. Separate plates from Brasher's Birds of North America and from Walcotts, Wild Flowers of North America, were acquired.

Authorized by the Budget Committee, 220 volumes from the Academy's serials were prepared for binding at a cost of $1000.00.

An inventory of Proceedings available was made and forwarded to the Secretary and where the number on hand so justified these were offered to the members as a gift.

As the Library consists chiefly of scientific and technical serials, some titles not too commonly held, its use is largely by loan to other libraries citing references in bibliographic tools. Among libraries outside the state requesting materials were those of such widely separated institutions as Michigan State University, University of Utah, Shell Development Co., Houston, Texas, Taft Sanitary Engineering Center, Cincinnati, Ohio, University of Illinois, and the Mobil Chemical Company of Metuchen, New Jersey.

Thirty-three new titles have been added.

In the absence of necrologist Dr. W. E. Edington, Dr. Winona Welch reported that four members of the Academy had passed away during the past year and would be reported on in the Friday sessions. They were: Scott V. Eaton, Thomas Lane, Harold Morrison, and Ward J. Rice.

Relation of Academy to State—W. A. Daily, Chairman: Dr. Daily reported that the Indiana State legislature has appropriated $4000 per annum to publish the Academy Proceedings for the years 1963 and 1964.

Dr. W. H. Johnson who served as the Academy representative on the AAAS Council reported that he had attended the council sessions in 1962 at Philadelphia and that the minutes of these sessions were published in Science.

Junior Academy—Dr. Thomas Overmire, State Sponsor: Dr. Overmire reported on a study he had made concerning the accomplishments of the 33 Junior Academy Best Girl and Best Boy awards: There are 5 with the Ph.D.; 1 with a M.D.; 3 with the M.A. or M.S.; 2 with the B.S. or B.A.; 3 are working on the Ph.D.; 2 on the M.A.; and 4 are undergraduates. Eight more had some college work.

Constitution Revision Committee—Dr. Paul Weatherwax, chairman: Dr. Weatherwax reported that the work on the revision was progressing and noted the need for expert legal help to be sure we met the legal requirements of non-profit corporations. He recommended that the present committee be reappointed or a new one appointed to continue the work.

Bonding Committee—Mr. Scott McCoy: Mr. McCoy sent in his report to the effect that the bond of the treasurer and trustees is in good order and would be renewed before its expiration date in Nov., 1965.

Visiting Scientists—Howard H. Michaud: Dr. Michaud submitted an extensive report for the files of the Academy. He reported a steady increase in participation in the program during the four years it has been in operation. During the first year 177 visits were made; 211 in the second; 238 in the third; and 246 last year. The most frequent requests are for visitors in the areas of Biology, Chemistry, Math, and Physics, in that order.

A motion was approved to recommend that the resolutions committee draw up appropriate resolutions recognizing the services of Dr. Leslie Willig as Director of Science Fairs, Dr. Sears Crowell as Director of the Indiana Science Talent Search, and Prof. Howard H. Michaud as state sponsor of the Junior Academy and director of the Visiting Scientist program.

Nomination Committee: The committee reported the nomination of Dr. Donald Cook and Mr. Scott McCoy as members of the Bonding Committee and that A. A. Lindsey be renominated as a member of the Research Grants Committee to succeed himself. The nominations were approved.

It was announced that Dr. W. P. Morgan had been appointed by Pres. Michaud to fill the unexpired term of Mr. Ward J. Rice as trustee of the Academy Foundation and that he would act as Chairman.

After considerable discussion on the cost of publishing the Proceedings and the immediate need of funds to meet the present printing bill, a motion was approved to transfer $600.00 from the Research Grants Account to the General Academy Budget Account.

A motion carried that the president appoint a committee to investigate ways to increase income either by dues increases or other means and report at the spring meeting.

The following recommendations were made by the Research Grants Committee:

Each applicant shall—

—submit 5 copies of his application to the Chairman of the Research Grant Committee, preferably at the annual fall meeting of the Academy.

—have been a member of the Academy for at least two (2) years at the time of the application. In the case of graduate students, the major professor, if qualified by membership, may make the application and be responsible for the project.

—be carrying on his project within the State of Indiana, and, if in the field of our natural resources or biota, be related to Indiana materials.

In general, the Committee will give priority to applicants at smaller institutions inasmuch as research funds are much less available there than at the larger state school. These recommendations were approved.

The meeting adjourned at 11:10 P.M.

WILLIAM W. BLOOM, Secretary

Approved 10-11-63

MINUTES OF THE GENERAL SESSION

October 11, 1963

The regular annual meeting of the Indiana Academy of Science was held in the Union Auditorium of Goshen College, Goshen, Indiana on October 11, 1963 at 9:30 A.M. The meeting was called to order by President Howard H. Michaud. Dr. Paul Mininger, President of Goshen College, welcomed the Academy to the campus. The minutes of the Executive Committee meeting of Thursday, October 10, 1963 were read by the secretary and approved as read.

In the absence of Dr. Will E. Edington, Academy Necrologist, Dr. Winona Welch read a brief biographical sketch of members who had died since the last annual meeting. These sketches are printed elsewhere in the proceedings.

As the main speaker at the general sessions, Dr. Richard M. Fagley, Executive Secretary, Commission of the Churches on Internation Affairs, The World Council of Churches, presented a very stimulating address on "The World's Expanding Populations".

The meeting adjourned at 11:00 for the beginning of the section meetings.

The annual dinner meeting of the Indiana Academy of Science was held in the Alumni Memorial Dining Room of Goshen College. Dr. Edward L. Haenisch, Vice-president of the Academy, presided. He introduced the guests and officers at the speaker's table and gave special recognition to out-of-state guests.

In the absence of Dr. L. E. DeLanney, Chairman of the membership committee, the secretary presented the applications of 38 individuals for membership in the Senior Academy. The applications were approved.

Dr. Lawrence Baldinger presented the following resolutions to the Academy which were approved:

1) That the secretary be requested to convey to Dr. Paul Mininger, President of Goshen College, the thanks of the Indiana Academy of Science for his cordial welcome, for the gracious hospitality of the institution, and for the efficient handling of the section meeting arrangements and facilities by Dr. Glen Miller, Chairman of the Program Committee, and his co-workers, Paul Bender, C. Franklin Bishop, Henry Weaver, Jr., Lester Zimmerman, and Jacob Swartzendruber, all of Goshen College, the personnel of the Alumni Memorial Dining Hall for their services in our behalf, and the committee for the Chapel Lecture Series which enabled us to hear Dr. Richard M. Fagley speak on "The World's Expanding Population" in the morning session.

2) That the secretary convey in writing to Dr. T. G. Yuncker of DePauw University, the thanks and best wishes of the Indiana Academy of Science for his long affiliation and sustained interest in

the affairs of the organization. Dr. Yuncker, formerly Chairman of the Department of Botany at DePauw University, has served the Academy as President and as a member of the Research Grants Committee. In his retirement and in spite of his recent illness, Dr. Yuncker has retained a keen interest in his scientific endeavors and in the welfare of the Academy. We wish him well ad multos annos.

3) That we make mention with special thanks the work of those members of the Academy whose interest and energies through the years have been directed toward stimulating the members of the younger generation into scientific careers and into membership in the Indiana Academy of Science, and that while we accept with regret the resignation from their endeavors with these young folks, this in order to undertake duties in their respective institutions, we do so with the hope that their good example will serve as a pattern and as a stimulus to the newer and younger members of the Academy for continuing this work with out budding scientists in the teen-age bracket.

4) That we note for commendation the work of the various special committees appointed by the president which has tended to improve the internal structure, to preserve the aims and purposes, and to present a purposeful external image of the organization for our members, and which has helped to enhance the general prestige of the Academy to the general public.

Dr. R. E. Girton, chairman of the Nominating Committee, presented the names of the divisional chairmen which had been elected in the divisional meetings earlier in the day. They are as follows: Anthropology, Wesley R. Hurt, Bloomington; Bacteriology, Robert Deufel, Indianapolis; Botany, P. A. Orpurt, North Manchester; Chemistry, Quentin Petersen, Crawfordsville; Entomology, Gertrude Ward, Earlham; Geology & Geography, J. Fraser Hart, Bloomington; History of Science, A. T. Guard, West Lafayette; Physics, Constantine Kolitsehew, Indianapolis; Plant Taxonomy, Robert Petty, Crawfordsville; Soil Science, John M. Robbins, Cannelton; Zoology, Robert H. Cooper, Muncie.

Dr. Girton then presented the slate for officers to be elected by the Academy. The slate consisted of the following: President, E. L. Haenisch, Crawfordsville; President-elect, F. J. Welcher, Indianapolis; Secretary, C. F. Dineen, St. Mary's College, Notre Dame; Treasurer, J. C. List, Muncie; Editor, R. Laubengayer, Crawfordsville; Membership Secretary, Carrolle Markle, Richmond; Press Secretary, F. N. Young, Bloomington; Member of the Research Grants Committee (5 years), A. A. Lindsey, West Lafayette; Members of the Committee for Bonding Trustees, Scott McCoy, Indianapolis and Donald J. Cook, Greencastle. A motion carried instructing the secretary to cast a unanimous ballot for the slate.

Following the conclusion of the business session, President Howard H. Michaud presented a challenging and informative address on "Science and the Conservation of Our Natural Resources."

Following the presidential address the meeting was adjourned.

WILLIAM W. BLOOM, Secretary

NEW MEMBERS—1963

Bailey, Dennis R., 2159 Waynoka Road, Euclid 17, Ohio — Z

Baumgart, Prof. John K., Mathematics Dept., Manchester College, North Manchester, Ind. — M

Bishop, Dr. C. Franklin, Goshen College, Goshen, Indiana — Bo

Bubelis, Walter, 513 S. Washington, Crawfordsville, Ind. — Bo

Burnham, Dr. Kenneth D., 3914 Burton Drive, Muncie, Ind. — Z

Carmony, Paul E., R. R. 3, Box 102, Alexandria, Ind. — E

Carroll, Dr. Henry, Indiana State College, Terre Haute, Ind. — Ph

Cole, Miss Victoria A., 1250 Meadowbrook Drive, Indianapolis 40, Ind. — A

Colins, Miss Janice Anne, 8944 Southmoor Ave., Highland, Ind. — A, Bo, Z

Cook, Timothy E., 1600 Manhattan Ave., Muncie, Ind. — Bo

Cowan, John D., Hort. Dept., Purdue University, Lafayette, Ind. — SS

Crosley, Theodore V., R. R. 2, Fairmount, Ind. — G

Dalgleisch, David L., III, 16 East Prairie Parkway, Brownsburg, Ind. — Bo, Z

Dassel, Herschel G., 1310 North Boeke Road, Evansville 11, Ind. — Ph

Derf, James R., 1013 Bayless, Plymouth, Ind. — G

Fraker, Mark Arnott, 204 East Drive, Lebanon, Ind. — Z

Frisch, Jack A., 125 North Roosevelt, Bloomington, Ind. — A

Furlow, John J., 2441 McLeay Drive, Indianapolis 20, Ind. — Bo, PT

Gaar, Mrs. Suzanne, 3003 E. 5th St., Anderson, Ind. — Z

Gibbs, Ronald K., Room 121, Jordan Hall, Indiana University, Bloomington, Ind. — Bo

Girdley, William Arch, 1155 Texas Ave., Grand Junction, Colo. — G

Godfrey, Martin R., 130 Martinsville St., Greencastle, Ind. — Z

Green, Miss Mary Jane, 3709 East St., Cincinnati 27, Ohio — Bo

Hannah, Peter R., 1517 "O" Street, Bedford, Ind. — SS

Harwood, Daniel L., 211 N. Grace, Crawfordsville, Ind. — Bo, Pt, Z

Heidt, Gary A., 1106 Bellevue Ave., South Bend, Ind. — Z

Hidy, Miss Carol L., 1401 N. Lesley, Indianapolis 19, Ind. — Bo, E, Z

Hile, Mrs. Jerry, 6 Judith Lane, Terre Haute, Ind. — Bo

Holliday, William G., 8618 Parkway Drive, Highland, Ind. — Z

Hosseinie, Mrs. Shidokht (Ostovany) 208 Evermann Apts., Bloomington, Ind. — E, Z

Huber, John J., 504 N. McKinely, Muncie, Ind. — Ba, Bo, C

Hurt, Dr. Wesley R., 150 Maxwell Hall, Indiana University Museum, Bloomington, Ind. — A

Jackson, Marion T., 2706 Underwood St., Lafayette, Ind. Bo

Kaufman, Dr. Karl L., College of Pharmacy, Butler University, Indianapolis 7, Ind. HS

Kitchell, James F., R. R. 7, Valparaiso, Ind. Ba, Z

Lennis, Larry J., 103½ S. Walnut St., Yorktown, Ind. Ba

LeVon, Miss Carolyn Sue, 522 N. Calvert, Muncie, Ind. Bo, E

Lincoln, William Edward III, 12 N. Temple, Indianapolis 1, Ind. C

Litto, Mrs. Ines Maria F., Hoosier Cts A-s, Bloomington, Ind. A

Louis, Dr. Nicholas B., Box 130, Valparaiso University, Valparaiso, Ind. Ps

McClary, Charles F., Bosse High School, 1300 Washington Ave., Evansville, Ind. C

McCracken, Mrs. Jean E., 1361 Third Ave., Terre Haute, Ind. Bo

McDowell, Miss Janey Mae, 2001 Anna Drive, Elkhart, Ind. HS

McFarland, Dr. John William, Chemistry Dept., DePauw University, Greencastle, Ind. C

Maysilles, Prof. James H., Box 63, Hanover College, Hanover, Ind. Bo, PT, E

Miller, Stephen A., 2011 N. 9th St., Terre Haute, Ind. Z, E

Mislivec, Philip B., 522 N. 7th St., Clinton, Indiana Bo

Oliver, Dr. Montague M., 1111 E. 19th Ave., Gary, Ind. Z

Olson, George B., 2322 S. 14th St., Niles, Mich. Ba

Orr, Alan R., Dept. of Biological Science, Purdue University, Lafayette, Ind. Bo

Patterson, Prof. Fred L., Dept. of Agronomy, Purdue University, Lafayette, Ind. Bo

Peters, Dr. Dennis G., Dept. Chemistry, Indiana University, Bloomington, Ind. C

Pleasants, Julian R., Lobund Laboratory, University of Notre Dame, Notre Dame, Ind. Ba

Predey, Dr. Thomas, 912 E. 167th Place, South Holland, Ill. Z

Pryor, Prof. William A., Dept. of Chemistry, Purdue University, Lafayette, Ind. C

Quigley, Stephen Robert, 1305 S. 6th St., Terre Haute, Ind. G

Reddy, Dr. Bandrau Sivarama, P. O. Box 447, Notre Dame, Ind. Ba, C

Reedy, Richard L., R. R. 2, Box 284, Middleton, Ind. E

Reuther, Ronald T., 1009 Merchants Bank Bldg., Indianapolis 4, Ind. Z, G

Rice, Dr. Francis Owen, Radiation Laboratory, Univ. of Notre Dame, South Bend, Ind. C

Rippy, Charles Lewis, Dept. of Zoology, Univ. of Kentucky, Lexington, Ky. Z

Rubin, David, Division of Science, Indiana State College, Terre Haute, Ind. Z

Schmidt, Miss Susan K., R. R. 1, 315 Carroll Rd., Ft. Wayne, Ind. Bo, E
Schneider, Dr. Allan F., Indiana Geological Survey, Indiana Univ., Bloomington, Ind. G
Seagrave, Miss Diane S., 119 E. Grant, Greentown, Ind. Bo, Z
Shands, Prof. Henry L., Dept. Botany and Plant Path., Purdue Univ., Lafayette, Ind. Bo
Shade, Richard Evan, Dept. of Entomology, Purdue Univ., Lafayette, Ind. E
Smith, Dr. Charles E., Jr., Ball State Teachers College, Muncie, Ind. Z
Smith, David Lee, 2006 Burlington Dr., Muncie, Ind. A, G, Z
Smith, Dr. Samuel W., 126 Gilbert Ave., Terre Haute, Ind. G
Springer, Charles S., Jr., 100 W. Norwich St., Columbus, Ohio C
Steinkamp, Erwin A., 817 Randolph Ave., Clarksville, Ind. Z
Stratton, James Forrest, 342 S. 6th St., Clinton, Ind. G
Talbott, Jan L., 1910 W. Second St., Marion, Ind. Z
Topping, James A., 1005 S. 19th St., Terre Haute, Ind. Z
Trankle, Dr. Robert J., Dept. of Biology, Franklin College, Franklin, Ind. Bo
Tucker, Gary R., 3101 Petty Road, Muncie, Ind. Z
Turner, Roosevelt, Univ. of California, Davis, Calif. SS
Von Meyer, William C., 1504 Port Jefferson Road, Sidney, Ohio Bo
Wise, Dr. Charles D., Dept. of Science, Ball State Teachers College, Muncie, Ind.
Withenbury, Miss Lesley, 110 Oak St., Glendale 46, Ohio Z
Yunker, Philip L., 3319 Oak Ave., Terre Haute, Ind. Ps

JUNIOR ACADEMY

Huntington High School Science Club, Huntington High School, Huntington, Ind.

INDIANA JUNIOR ACADEMY OF SCIENCE

OFFICERS FOR 1963

President: Kathryn Crider, North Central High School, Indianapolis
Vice President: John Gaiser, University High School, Bloomington
Secretary: Vicki Schmidt, Franklin Central High School, Acton

MEMBERS OF THE COUNCIL

Sister Suzanne, Chairman, Vincennes (1959-1963); V. C. Cripe, South Bend (1960-1964); Don R. Winslow, Bloomington (1961-1965); Helen Reed, Indianapolis (1962-1966); Erwin Steinkamp, New Albany (1963-1967).

PROGRAM OF THE THIRTY-FIRST ANNUAL MEETING

October 12, 1963

Science Building, Goshen College, Goshen, Indiana.

8:30-10:00 A.M. Registration and Placement of Exhibits.

10:00-11:00 A.M. Conferences in Science and Mathematics by faculty representatives of Goshen College.

11:00-12:00 Noon. Visits to Instructional Facilities and Laboratories of Goshen College.

12:00 Noon. Luncheon, College Cafeteria.

1:15 P.M. General Assembly, Assembly Hall, Kathryn Crider, presiding.
Greetings, William Miller, Registrar of Goshen College.
Business Meeting, and Presentation of Awards.

1:30-3:30 P.M. Presentation of Papers.

Section A (Grades 11 and 12), Assembly Hall, President Kathryn Crider, presiding.

The following papers were read by members of the Junior Academy:

1. Microbial Enzymes that Produce Rancidity in Selected Fats and Oils, Deborah Gano, Science Club, Washington High School, Indianapolis.
2. The Sea in Our Future, Bert Guentert, Adams Walton Club, John Adams High School, South Bend.
3. Nucleotide Sequence Studies Using AMP as a Model Fibre and Subsequent s-RNA Extraction for Future Fractionation, Gary Gunther, Science Club, Washington High School, Indianapolis.
4. The effects of Heat on Stainless Steel and Titanium, Daniel M. Hoban, Albertus Magnus Science Club, Central Catholic High School, Fort Wayne.

5. Subcutaneous Induction of Malignant Melanoma in the Syrian Hamster with Cell-Free Extracts, Rhea Louise Keller, Phi-Chi Science Club, New Haven High School, New Haven.
6. Preliminary Program for the Use of a Formalized Language for the Assertion of 12-Note-Class Composition and Demonstration of Basic Acoustical Properties, Edward Long, E. Wayne Gross Academy of Science, University High School, Bloomington.
7. Thymectomization and the Effects of Thymus Heterographs, Gregory Lumbra, E. Wayne Gross Academy of Science, University High School, Bloomington.
8. Establishment of Indigenous Microbial Flora in the Intestine of Laboratory Mice, Janice Perryman, Sigma Mu Club, Franklin Central High School, Acton.
9. Triaxial Coordinate System, Jerry Shepherd, Science Club, Washington High School, Indianapolis.
10. Sensation and Perception of Vision, Don Van Hoy, National Scientific Honor Society, Bloomington High School, Bloomington.
11. The Succession of Protists and Associated Forms in a Fresh Water Culture, Kathryn Crider, North Central High School, Indianapolis.

Section B (Grades 8 to 10), Room 101, Science Building, Vice President John Gaiser, presiding.

12. A Comparative Study of Common Metals and Metallic Oxides Used as Catalysts in Liberating Oxygen, Jack C. Dahl, Sigma Mu Club, Franklin Central High School, Acton.
13. Photographic Dosimetry, Tom Elam, MSE Academy of Science, University Junior High School, Bloomington.
14. How to Make an Incubator, Eugene Fox, Biology Club, Lew Wallace High School, Gary.
15. City Limits—But Bacteria Can't Read, Alison Lumbra, MSE Academy of Science, University Junior High School, Bloomington.
16. Proving by the CLB Method that x-Rays Produce Lethal Mutations in Drosophila, Tulle Hazelrigg, Freshman Academy of Science, University High School, Bloomington.

Minutes of Indiana Junior Academy of Science

The thirty-first annual meeting of the Indiana Junior Academy of Science was held Saturday, October 12, 1963, on the campus of Goshen College, Goshen, Indiana. The meeting was attended by 164 members, sponsors and guests. Representatives of 16 member clubs were in attendance.

Conferences in science and mathematics were held at 10 A.M. by members of the faculty of Goshen College. The areas of science that were discussed are listed in the program. Junior Academy members found this part of the program to be especially interesting. Visits to the instructional and laboratory facilities of the college were made between 11:00 A.M. and 12:00 Noon.

Following luncheon in the College Cafeteria, the more formal part of the program began. The afternoon general session was held in the Assembly Hall of the college.

The meeting began at 1:15 P.M. with opening remarks by the president, Kathryn Crider. The Junior Academy was officially welcomed to the campus by Mr. William Miller, Registrar of Goshen College. Mr. Miller gave a brief, interesting comparison of Russian and American attitudes toward science. He also commented on the importance of science and stressed especially the need for scientists and science teachers.

The current officers of the Junior Academy were then introduced to the assembled members. In addition, two members of the Council, Miss Helen Reed and Mr. Don R. Winslow, were introduced. The president announced that Mr. Keith Hunnings of New Haven High School and Sister Marian Francis of Reitz Memorial High School, Evansville, have become members of the Council. These new Council members will replace Sister Suzanne, Vincennes and Mr. V. C. Cripe, South Bend.

The results of the election of officers for 1964 were as follows: President, Gary Gunther, Science Club, Washington High School, Indianapolis; Vice President, Bert Guentert, Adams Walton Club, John Adams High School, South Bend; and Secretary, Susan Mann, E. Wayne Gross Academy of Science, University High School, Bloomington. Balloting for the election of officers was conducted by mail a few days before the meeting. Each member club was entitled to one ballot.

The award for "Best Boy in Science" was given to Gregory Lumbra, E. Wayne Gross Academy of Science, University High School, Bloomington. "Best Girl in Science" awards were received by Kathryn Crider, North Central High School, Indianapolis, and Rhea Keller, Phi-Chi Club, New Haven High School, New Haven. The recipients of these awards were selected by the Council from a list of students who had been nominated by club sponsors. Personal interviews were included as part of the reviewing process. Recipients of the honor received one year memberships in the American Association for the Advancement of Science.

Dr. Thomas Overmire, State Sponsor of the Junior Academy, discussed briefly some results of a follow-up study that is being made of the 33 Junior Academy members who were judged "Best Boy or Best Girl in Science" between the years 1940 and 1960. Preliminary results of this survey show that at least six of this group have earned the doctorate, at least three others have earned the masters degree, at least two others have earned the bachelors degree, and at least nine others are currently in college.

Sixteen papers, as listed in the program, were read during the remainder of the program. The presentation of papers was held in two con-current sessions. Section A was for papers by students in the 11th or 12th grades, and Section B for students in grades 8 through 10. The papers represented a wide variety of topics. All of the papers were well received by the members in attendance at the meeting.

Following the session on papers, the president, Kathryn Crider, introduced Dr. A. S. Kester and Dr. C. E. Brownewell of Miles Labora-

tories who were representing the American Society of Microbiologists. Dr. Kester and Dr. Brownewell announced that the award for the best paper in the area of microbiology was to be given to Rhea Keller, Phi-Chi Club, New Haven High School, New Haven. The award consisted of a check for twenty-five dollars.

The president, speaking for the members of the Junior Academy, then thanked the faculty and representatives of Goshen College for their important part in the success of the day's program. It was announced that the 1964 meeting will be held at Indiana Central College in Indianapolis.

The meeting was adjourned at 3:30 P.M.

VICKI SCHMIDT, Secretary

INDIANA JUNIOR ACADEMY OF SCIENCE CLUBS

CURRENT LIST, FALL OF 1963

Towns	*School and Club*	*Sponsor*
Acton	Franklin Central, Sigma Mu (1958)	Jerry Colglazier
Bloomington	H. S., Nat. Scientific Honor Soc. (1931)	Merril L. Crisler
Bloomington	University Jr. H. S., MSE Club (1960)	Chas. Souers
Bloomington	University H. S., Freshman Acad. of Sc.	Bill Stucky
Bloomington	University H. S., E. Wayne Gross Acad. of Sc. (1938)	Lew Wise
Chesterton	H. S., Science (1954)	Robert McCord
Clarksville	Our Lady of Providence H. S., Phy-Chem (1956)	John Chilks
Clayton	H. S., Jr. Academy (1951)	Howard C. Leslie
Columbus	Jr. H. S., Academy of Science (1959)	Albert Sheets, Jr.
Columbus	Senior H. S., Science Club (1958)	L. N. Carmichael
Connersville	Alquina H. S., Science Club (1960)	Walter Gronning
Crawfordsville	H. S., Up-N-Atom (1950)	David Wells
Edinburg	H. S., The Alchemists (1954)	S. C. Harrell
Elkhart	H. S., Jr. Academy (1940)	Robert Mahan
Evansville	Reitz Memorial H. S., Phi Chi Mu (1958)	Sr. Francetta Sr. Peter
Fort Wayne	Central H. S., Biology (1940)	
Fort Wayne	Central Catholic H. S., Albertus Magnus Science Club (1952)	Sr. Winifred Sr. M. Magdelen S.P. Sr. Jean Margaret S.P.
Fort Wayne	Elmhurst H. S., Phy-Chem (1935)	Ruth Wimmer
Fort Wayne	North Side H. S., Nature (1936)	
Fort Wayne	South Side H. S., Jr. Acad. of Sc. (1956)	Robert Weber
Gary	Lew Wallace H. S., Biology (1935)	Lola Lemon
Gary	Lew Wallace H. S., Klub Kem (1941)	Helen McKenzie
Gary	Tolleston H. S., Biology (1952)	
Gary	Tolleston H. S., Future Scientists of America (1949)	Arthur Kline
Gary	Wirth H. S., Biology (1945)	Mrs. Frances Huddleston
Gas City	Mississinewa Joint H. S., Science (1936)	Roy McKee
Griffith	H. S., Science (1953)	George M. Bunce

Towns	*School and Club*	*Sponsor*
Hamlet	H. S., Science (1954)	Lawrence Cushman
Highland	H. S., Science (1961)	
Hobart	H. S., Science (1952)	Lola Stewart
Huntington	H. S., Science (1963)	Robert Diffenbaugh
Indianapolis	Fulton Jr. H. S., Science (1962)	Mrs. Berdine Proctor
Indianapolis	Howe H. S., Science (1949)	Jerry Motley
Indianapolis	Ladywood School, Guerin Science (1957)	Sr. Pauline Marie Sr. Louise
Indianapolis	Manual H. S., Sat. Morning Science (1962)	Wayne E. Dunbar Helen Reed
Indianapolis	Saint Agnes Academy, Science (1959)	Sr. Amelia
Indianapolis	Shortridge H. S., Naturalists' Club (1947)	Robert A. Weaver
Indianapolis	Shortridge H. S., Science (1931)	Mrs. H. A. Parker
Indianapolis	Technical H. S., Nature (1932)	Chas. E. Russell
Indianapolis	Washington H. S., Science (1931)	Mrs. E. H. Crider
Indianapolis	Westland Jr. H. S., Science (1959)	John Van Sickle
Jeffersonville	Clark and Floyd County Seminar (1959)	Dr. Richard L. Mauer Alan Drive New Albany, Indiana
LaPorte	H. S., Bi-Phi-Chem (1958)	Francis M. Gourley Byron Bernard
Lebanon	H. S., Jr. Explorers of Science (1953)	Tom Ewing
Loogootee	St. John H. S., Science (1959)	Sr. Mary Ellen
Madison	Fr. Michael Shawe Memorial H. S., Shawe Science (1957)	T. A. Winkel
Mishawaka	H. S., Science (1936)	
New Albany	H. S., Science (1935)	Erwin Steinkamp
New Castle	H. S., Science (1947)	Betty Jo Montag
New Haven	H. S., Phi-Chi (1954)	Keith Hunnings
Oldenburg	Imm. Conception Academy, Heterogeneous Geniuses (1958)	Sr. M. Constance
Richmond	H. S., Science (1950)	Von Alexander
Rossville	H. S., Science (1954)	Martin Silverthorn
Sandborn	H. S., Up and Atom (1954)	
South Bend	Central H. S., JETS (1939)	Lawrence K. Cox
South Bend	John Adams H. S., Adams Walton (1953)	Ernest Litweiler
Terre Haute	Schulte H. S., Pius X Science Teens (1961)	Sr. Thomas Mary
Vincennes	St. Rose Academy, Sigma Tau (1959)	Sr. Suzanne
Washington	Washington Catholic H. S., Aquinas Science (1958)	Sr. Marian Francis

NECROLOGY

Will E. Edington, DePauw University

Scott Verne Eaton

Liberty, Indiana
November 7, 1885

Valparaiso, Indiana
February 16, 1963

Few of us realize the tremendous and important role that a deficiency or excess of some chemical plays in causing ill health or other weakness in all living things, animal and vegetable. This is an age of vitamins, food supplements, hormones, fertilizers, antibiotics, vaccines, etc. Thousands of scientists: chemists, physicians, veterinarians, botanists, bacteriologists, horticulturists, physiologists, nutritionists and others in hundreds of great university, industrial and commercial laboratories, hospitals and medical clinics, are searching for causes and effects of deficiencies and excesses of nitrogen, calcium, phosphorus, potassium, sodium, sulphur, fluorine, iodine and many other elements and chemical compounds in humans, animals and plants.

Scott Verne Eaton was a plant physiologist who devoted the major part of his scientific and professional life to the study of the effects of deficiencies and excesses of certain chemicals on the growth and metabolism of plants. He published numerous papers in the Botanical Gazette, Plant Physiology, and other journals on the growth and chemical composition of a plant deprived of a needed chemical element, such as sulphur in the soybean, sunflower, black mustard and tomato, potassium and phosphorus in the sunflower, boron in a number of plants, and others. His work was done in the botanical laboratories of the University of Chicago where he spent thirty years in research and teaching, mainly in the Graduate School where he offered courses in Plant Chemistry, Microchemistry, and Plant Production, and directed research work of students in his field.

Scott V. Eaton was born on a farm near Liberty, Indiana, on November 7, 1885, one of four brothers whose ancestors settled on this farm before Indiana became a State. Following the completion of his public school education he entered Earlham College where he received the A.B. degree in 1908. After several years of teaching Latin in a high school of which he was also assistant principal, he enrolled in the University of Chicago in 1912 and received the M.S. degree in Botany the following year. He then served four years in Washburn College, Topeka, Kansas, as an instructor and assistant professor of botany. He then spent the year 1918-1919 as an assistant plant physiologist in the Maryland Experiment Station. He returned to the University of Chicago in 1919 as a graduate student and assistant in botany, received the Ph.D. degree in Plant Physiology in 1920, was made an instructor in 1921 and an assistant

professor four years later. He was promoted to an associate professorship in 1949 and retired in 1952 as an Emeritus Associate Professor of Botany.

Following his retirement he and Mrs. Eaton secured them a home two miles from Valparaiso, Indiana, where he had an acre of land and he devoted much of his remaining years to developing a small orchard of various kinds of dwarf fruit trees, cultivating perennial plants and flowers, and working in his vegetable garden. Throughout his professional life he and his family spent many summer vacations in the Rocky Mountains in Colorado, and later in the far Northwest where one of his two daughters had her home.

Dr. Eaton was active in professional scientific societies. He early became a member of the American Society of Plant Physiologists and served this organization as its secretary-treasurer from 1926 to 1928, vice-president the following year and president in 1929-1930. He joined the American Association for the Advancement of Science in 1917 and was made a Fellow in 1921. He was also a member of the Botanical Society. He joined the Indiana Academy of Science in 1953 but he presented no papers before the Academy. Dr. Eaton was elected to Sigma Xi in 1918 and he was listed in American Men of Science.

He joined the Hyde Park Baptist Church in Chicago in 1922 and was active in its work, serving as chairman of the Board of Deacons and in other capacities. He remained a contributing member until his death.

Dr. Eaton died on February 16, 1963, in Porter County Hospital in Valparaiso, following an attack of coronary thrombosis and a stroke ten days earlier. He had lived a useful life as a churchman and an excellent and productive scientific worker and teacher.

THOMAS JAMES LANE

Merrill, Wisconsin — Notre Dame, Indiana
May 1, 1906 — September 25, 1963

Five days after he had completed a year of sabbatical leave from the University of Notre Dame, spent in research in the Argonne National Laboratory, north of Lemont, Illinois, Thomas James Lane, C.S.C., was found dead from natural causes in his room in Corby Hall on the Notre Dame campus. Before going to Argonne he had been associated with Notre Dame's Radiation Laboratory and was directing two research projects of the Chemistry Department supported by the National Institutes of Health.

Thomas James Lane was born in Merrill, Wisconsin, on May 1, 1906. At the age of fourteen he entered the Holy Cross Seminary on the Notre Dame campus on September 4, 1920, and received the habit on July 1, 1924. He continued his study at Notre Dame and received the A.B. degree in 1924. He made his final profession of vows on July 1, 1929, and he was ordained to the priesthood in Sacred Heart Church on the Notre Dame campus on June 24, 1933. He then enrolled in Catholic University, Washington, D. C., and received the M.S. degree in 1935. He spent the next five years as an instructor in chemistry at the University of Port-

land, Oregon, following which he returned to Notre Dame and completed the requirements for the Ph.D. degree which was conferred on him in 1942. He then returned to the University of Portland and remained there until 1945. He spent the next year at St. Edward's University in Austin, Texas, following which he returned to Notre Dame for a year as an instructor in chemistry. He then taught two years at King's College, Wilkes-Barre, Pa., as professor of chemistry, and spent the following two years at Stonehill College, North Eaton, Mass. He returned to Notre Dame in 1951 as an instructor in chemistry, was promoted to Assistant Professor in 1953 and Associate Professor in 1955, which position he held at the time of his death on September 25, 1963.

In his earlier years at Notre Dame Father Lane taught general chemistry. Later he taught advanced courses in chemistry on both the undergraduate and graduate level. At the time of his death he was teaching only on the graduate level, a course in Inorganic Chemistry Preparations, and he was directing four doctoral dissertations and had two post-doctorates working with him. Since 1955 he had been working on National Institutes of Health and Atomic Energy Commission projects. He was the author of about 50 research articles which were published in the Journal of the American Chemical Society, the Journal of Physical Chemistry, the Journal of Inorganic Chemistry, and other journals.

One of the highlights of his career occurred when he went to Europe in 1959 to attend the International Congress of Polarography held at Cambridge University in England on August 24 to 29, at which he presented a technical paper on "Thiourea, Alkyl Substituted Thioureas and Their Metal Complexes." The following month, on September 5 to 12, he attended the International Congress on Molecular Spectroscopy, meeting in Bologna, Italy.

He was a member of the American Chemical Society and was listed in American Men of Science. He joined the Indiana Academy of Science in 1961 and was known to only a few members of the Academy.

Father Lane was a sympathetic and kindly teacher who, however, insisted on rigor and serious study. His most effective work was done in directing the graduate study of students in his fields of study.

He completed his year of research at the Argonne Laboratory on September 20, 1963. On learning of his death five days later Dr. Herbert Hyman, Director of the Argonne Laboratory, sent a floral offering, a tribute "To a worthy colleague and valued collaborator and a gentle friend."

HAROLD MORRISON

McCordsville, Indiana — Washington, D. C.
May 24, 1890 — March 11, 1963

The widespread public concern following the publication of Marine Biologist Rachel Carson's book, "Silent Spring," pointing out the dangers of the indiscriminate spraying of DDT and other insecticides and calling for government controls, led to the appointment of a U. S. Senate Com-

mittee to investigate the situation. It was brought out that the retail sale of agricultural insecticides and household insecticides and repellants in the United States amounts to one billion dollars annually. A Public Health Service toxicologist testified that DDT had been found in small amounts, for the most part harmless, in every meal analyzed in this country, and the President of the National Agricultural Chemicals Association testified that food abundance taken for granted by modern countries would quickly turn to famine without insecticides. Obviously entomology and entomologists play and will continue to play a fundamental role in the world economy. The U. S. Department of Agriculture, the great Land Grant Colleges and the great industrial chemical laboratories have made our country the world leader in agricultural production.

With the death of Harold Morrison on March 11, 1963, in Washington, D. C., the United States lost one of its great entomologists. He had long been an internationally known and consulted taxonomic authority on Coccoidea, pests more familiarly known as scale, mealy bugs, et cetera, which infest our forests, orchards, farms, gardens and plant life in general. In a report made to the Indiana Academy in 1953 by D. L. Schuder of Purdue University at least 73 species of this pest were known to exist in Indiana.

Harold Morrison was born in McCordsville, Indiana, 15 miles northeast of Indianapolis, on May 24, 1890. An only child, at the age of nine he and his parents moved to Indianapolis where he completed his precollege education and graduated from Shortridge High School where an outstanding teacher of science, Miss Rousseau McClelan, influenced him to continue his study in natural science, particularly entomology. Through contacts with President David Starr Jordan, of Stanford University, and the reputation of Dr. Vernon Kellogg as a professor of entomology, he entered Stanford. He remained there five terms and then transferred to Cornell University where he graduated in 1914 with the A.B. degree. At both Stanford and Cornell he excelled in the high jump and other track events in intercollegiate trackmeets. After graduation he returned to Stanford for a year of graduate study and received the A.M. degree in 1915. In 1910 he had become associated with the State Entomologist in Indianapolis as an assistant entomologist and except for the year of graduate study at Stanford he served the State until 1916. Also during this time he collaborated with Harry Dietz in the study and publication of two papers on scale insects. One of these papers, "The Coccidae or Scale Insects of Indiana," illustrated by R. E. Snodgrass, was comprehensive and was published by the State Entomologist's office, and established Morrison's reputation as an outstanding entomologist and authority on Coccidae.

In 1916 Mr. Morrison joined the U. S. Department of Agriculture as a plant quarantine inspector for the Federal Horticultural Board. The next year he became an entomological explorer in the Bureau of Entomology and Plant Quarantine. He spent the year 1919-20 in the West Indies collecting coccids and other insects. In 1920 he was made an assistant entomologist and the Bureau's scale insect specialist. He was promoted to associate entomologist in 1924, entomologist the following year and senior entomologist in 1928, which position he held until his retirement

in 1953. He was in charge of the Bureau's taxonomic investigations from 1928 to 1935. Because of the insistence of the then Director of Research of the Department of Agriculture Mr. Morrison took his wife and son and spent the year 1924-25 in Boston in order to complete a year of residence study for the doctorate at Harvard. He completed his thesis out of residence and received the Sc.D. degree in 1927.

After his retirement he was a collaborator in the Entomology Research Division and spent several hours a day in his office working on coccid material. However, his health began to fail several years before his death, and rapidly during his last year, and he entered the Washington Hospital Center on February 19, 1963. Three days later he suffered a severe stroke that caused his death on March 11, 1963.

During his long tenure in the Bureau of Entomology he was the author or joint author of 30 papers on coccoidea, 27 of which were systematic studies. All these papers are detailed and many of them comprehensive. His last published paper, "A Selected Bibliography of the Coccoidea," covering the literature up through 1955 and compiled with the assistance of Miss Alice V. Renk, gives a complete list of his taxonomic papers. Early in 1963 he and his wife, a Cornell trained entomologist, completed a supplement to the preceding work and submitted it for publication.

Dr. Morrison was a dedicated entomologist. His co-worker, Louise M. Russell, who prepared a Memorial for him for the Proceedings of the Entomological Society of Washington, states: "The eminence of Dr. Morrison as a coccidologist was recognized by coccid workers around the world. * * * He pioneered in the preparation of specimens for microscopic examination, and his contributions in this area have contributed immensely to the perception of morphological characteristics of scale insects and other microscopic arthropods. He was the first coccidologist to devise a classification of a family of the Coccoidea based on all available stages and instars of the insects."

Dr. Morrison joined the Entomological Society of Washington in 1916 and was its second vice-president in 1931. Also in 1931 he was one of the vice-presidents of the Washington Academy of Sciences. He became a member of the American Association for the Advancement of Science in 1917 and was made a Fellow in 1920. He was also a Fellow of the Entomological Society of America and a member of the Cambridge (Mass.) Entomological Club, the Canadian Entomological Club and Sigma Xi. He held honorary memberships in the Royal Spanish Society of Natural History and the Netherlands Entomological Society. He was listed in American Men of Science. He joined Indiana Academy of Science in 1910 and was made a Fellow in 1962. He joined the Cosmos Club in Washington, D. C., in 1924 and remained an active member and made frequent use of the Club's facilities until shortly before his death.

He was critical, thorough, cautious and uncompromising not only in his own work but also in evaluating the work of others. He was a foe of all forms of waste and especially of government deficit spending which led him to be pessimistic about the future of the United States. He loved to work with machinery and mechanical devices. He designed and built a head rest that included a plaster cast for his forehead which enabled

him to spend long hours comfortably examining coccid specimens through his binocular compound microscope.

Dr. Morrison inherited a farm near Indianapolis and he and Mrs. Morrison spent some time of their annual vacations at the farm where he examined and directed the work of his tenant. Following his death in March his body was laid to rest near Noblesville, Indiana, not far from his birthplace.

WARD JENNINGS RICE

Roachdale, Indiana — Indianapolis, Indiana
February 21, 1890 — September 16, 1963

The Indiana Academy of Science has been very fortunate throughout this century to have had a number of prominent members and workers who belonged to the great Eil Lilly and Company organization. One familiar with the history of the Academy readily recalls names great in Academy history such as John S. Wright and Eli Lilly, Jr., who served as Presidents, and others who have supported the Academy both in the past and at the present. Such a member was Ward Jennings Rice who spent his entire professional career totaling 43 years as a bacteriologist and analytical chemist with Eli Lilly and Company. During the past thirteen years he had served the Academy as a Trustee of the very important Academy Foundation Committee and he was its Chairman at the time of his death.

Ward Jennings Rice was born at Roachdale, Indiana, on February 21, 1890. Following his graduation from the Roachdale High School in 1907, he entered Purdue University and received the B.S. degree in 1911 with chemistry as his major field of study. On June 1, 1911, he began his long career with Eli Lilly and Company. In 1926 he became Head of the Analytical Department, in chemistry, and four years later he was promoted to Director of Quality Control. He not only possessed considerable research ability but he was also an excellent administrator so that in 1950 he was made Executive Director of Control which position he still held at the time of his retirement in February, 1955.

For many years preceding his retirement Mr. Rice was an active member of the Combined Pharmaceutical Committee, a permanent committee of the American Drug Manufacturers Association and the American Pharmaceutical Manufacturers' Association, devoted to the standardization of pharmaceutical products. In this capacity he made many important contributions.

He was also very active in the work of the United States Pharmacopeia Convention, the organization that controls, revises and publishes the U. S. Pharmacopeia, most of whose work in the standardization of pharmaceutical products is done by committees and subcommittees, since the Convention meets only decennially. Mr. Rice served as Chairman of a subcommittee on the assay of digitoxin, a glucoside derived from digitalis, and the results of his work were published in various editions of the Pharmacopeia. He was also "instrumental in establishing pharmacopeial standards for Amobarbitol and other barbiturate products and

was responsible for the establishment of the standards for dosage forms of diethylstilbestrol which appear in the U. S. Pharmacopeia." Also the pharmaceutical industry recognizes the standards he set up for maintaining the quality of crude ergot from domestic sources. At the time of his retirement from Eli Lilly and Company he was a member of the Committee of Revision of the National Formulary and chairman of the subcommittee on cyclic compounds. Other than in the U. S. Pharmacopeia Mr. Rice did not publish the results of any of his scientific work.

Through the years he had been deeply interested in bird study and since 1907 he had kept a daily record of the birds he saw and identified. After his retirement he devoted much of his time to ornithology. He had long been a member of the American Ornithologists' Union, the National Audubon Society, the Indiana Audubon Society and the Indianapolis Society. He was also interested in travel, stamp collecting and working with fine varieties of iris.

Mr. Rice was a member of the American Association for the Advancement of Science, the American Chemical Society, the American Pharmaceutical Association and the Navy League. He was a member of the Second Presbyterian Church in Indianapolis, the Roachdale Masonic Lodge, and the Scottish Rite and Murat Shrine in Indianapolis. He joined the Indiana Academy of Science in 1940 and, following the death of Frank B. Wade in 1950, the Academy elected him as a Trustee of the Academy Foundation. He became Chairman of the Academy Foundation in 1957 and served conscientiously and efficiently in this capacity until his death.

Ward J. Rice was a tall, striking and impressive looking man whose hair in his later years became snow-white and contrasted sharply with his ruddy complexion. Although in his retired years he did not do much scientific work, nevertheless in his death in Indianapolis on September 16, 1963, the pharmaceutical industry lost an able and efficient scientist and the Academy a useful and valuable member.

PRESIDENTIAL ADDRESS

Science and the Conservation of Our Natural Resources

HOWARD H. MICHAUD, Purdue University

The Meaning of Conservation—

The meaning of conservation has been so segmented by pre-conceived notions that it is hazardous to attempt to focus attention upon a single interpretation acceptable to everyone.

The late Gifford Pinchot (1) described conservation as a new governmental policy that brought into close relationship such renewable resources as forests, rangelands, waters and wildlife and he advocated the need for unifying their management into a single land-use program. For the definition of conservation, however, Pinchot gave credit to Dr. W. J. McGee, head of the Bureau of American Ethnology during the administration of Theodore Roosevelt. McGee defined conservation as the use of natural resources for the greatest good of the greatest number for the longest time. This meaning of conservation holds wide acceptance even today among resource specialists.

Many other viewpoints concerning conservation have been expressed by other writers. For example, Paul B. Sears (2) said, "Conservation is not a subject, but a point of view." Writing about conservation, Aldo Leopold (2) said, "A thing is right only when it tends to preserve the integrity, stability and beauty of the community; and the community includes the soil, water, fauna and flora, as well as the people." An unknown author said, "Conservation is intelligent cooperation with nature."

The foregoing quotations are indicative of the voluminous semantics that have evolved since the turn of the century when the idea of conservation of our natural resources first was called to the attention of the American people.

The idea of conservation gained its first roots among the scientists of the nation. Colonel Richard Lieber, first director of the Indiana Department of Conservation, said, "The thought of conservation started not with the user, let alone the despoiler, but rather from the scientist's workshop." (3) The reason for *this statement* stems from the initial concern voiced by the American Association for the Advancement of Science over the loss of our nation's forest resources. In 1873, and again in 1890, the association sent memorials to Congress and to the states asking that laws be enacted for the protection of forests. In 1897, the National Academy of Sciences followed with a statement of its own concerning the protection of our natural resources.

The beginning of the conservation movement in the United States is commonly associated with the White House Conference of Governors called by President Theodore Roosevelt in 1908. Following the conference, President Roosevelt appointed a National Conservation Commission con-

sisting of forty-nine men representing about equal numbers from the ranks of scientists, politicians and industrialists. A year later (1909), the commission submitted the first comprehensive inventory of the nation's resources. The second immediate result of the White House Conference of Governors was the appointment of state conservation agencies in forty-one of the states by governors who had come to recognize the necessity for such action.

Time does not permit a comprehensive discussion of the historical development of the conservation movement in the United States. It is sufficient to say that the scientists of the nation were among the first to become concerned about the profligate handling of the natural resources of the nation.

Conservation is often defined as the wise use of our natural resources. I should like to place greater emphasis on man's obligation with regard to such use by saying that conservation means the wise use and *management* of our natural resources to make them last for the longest possible time. Resources are of no value to man unless thay can be used. The confusion associated with the idea of conservation results largely over the controversy of opinion as to what constitutes wise use, both for the present as well as the future.

There are several other reasons why conservation seems to be frought with bewilderment. First, and foremost perhaps, is that the solution of conservation problems is interdisciplinary. Often, such problems may be resolved only by application of social, economic and scientific considerations. Our primary resource objective is to maintain the quantity and quality of natural resources. The accumulated benefit in human welfare is a social objective. Our scientific technology with regard to effective management of natural resources frequently is far ahead of our application of such knowledge. Because of this we depend upon public aids, legal controls and public education. These are social measures to promote conservation. The scientist may have forgotten long since that he is an important cog in the whole procedure that leads toward more adequate protection of our resource base.

A second source of confusion originates within the ranks of the scientifically trained resource specialists. In this group are the agronomists, foresters, wildlife biologists, hydrologists, geologists, geographers, fisheries biologists, and sanitary engineers. Disagreement over what constitutes the best use of specific resources may be as common among the specialists as among lay groups.

A third roadblock to better conservation understanding is the lack of confidence of the lay citizen in the results of scientific research, perhaps confounded by the scientists' unwillingness to compromise. As Ernest Swift says, "There are substantial numbers of specialists and technicians who alienate a large segment of an otherwise sympathetic public by their narrow motivations and intolerance of a rather broad and varied public interest. If the professional conservationists are leaving the public behind—and this is happening in some fields—it is partially their own fault. Whether they work for private industry or a public agency, their interest must blend with public acceptance if they expect to gain intelligent support." (4)

These introductory remarks are presented in the hope of establishing a degree of understanding as to why conservation presents such a diverse and complex area. My chief concern is to discuss the relation of science to conservation and especially how the various sciences contribute to effective management of our natural resources.

Special Conservation Problem Areas That Need Scientific Solution—

The following question appeared in the American Institute of Biological Sciences Newsletter of March, 1960, "Doesn't the American public deserve better answers than it has been getting in such controversial matters as cranberries vs. aminotriazole, pest controls vs. wildlife, sewage disposal—algae—pollution control, space vehicle ecology, nutrition, population pressure and many, many others?"

"Finally, if the response to this is "Yes," shouldn't the biologists, rather than others, be providing the answers?" (5)

Most of the problems named are conservation problems, yet it is doubtful whether the biologists themselves should commonly classify them as such. Many scientists are working towards solution of problems to improve the resource-use relationship between man and his environment. In such cases, immeasurable dignity may be conferred to conservation, if the scientist identifies his contribution as such.

The two primary problems relating to soil conservation are (1) to control erosion and (2) to maintain the fertility of the soil. Volumes of research have been published on such studies. Yet, soil science is a relatively new field and represents a complex science involving physics, chemistry, biology, ecology, climatology and mathematics.

The late Dr. George D. Scarseth suggested several interesting specific soil conservation problems that needed solutions. (6) These were called hypotheses because they were ideas evoked through observational evidence and could not be substantiated in fact without scientific experimentation. Two of the nine examples given are (1) "Does cornstalk rot develop in very heavy stands of 20,000 stalks or more per acre because of a shortage of carbon dioxide (CO_2)? (2) Since sunlight is one of our most valuable resources, do we waste it in the spring by waiting for the soil to warm before planting?" In the latter, it was suggested that as the soil warms, soil microorganisms release nutrients, especially nitrogen, for crops. So we may not need to wait for the soil to warm, because the nutrients can be supplied in forms ready for the plant to use.

The use of mineral resources presents somewhat different problems because unlike the biological resources, minerals are non-renewable. Duncan J. McGregor, Indiana Geological Survey, in an unpublished paper said, "To be assured of continued and adequate supplies of minerals, we must devote every effort to finding more efficient ways of discovering new mineral deposits, of extracting minerals from deposits currently being developed, of using lower grade ores, of finding new uses for the most abundant minerals, and of finding substitutes for those minerals which are being exhausted, or for those which are difficult to obtain." (7)

There are myriad other resource-use areas that are in need of scientific investigation. The history of any one science is replete with illustrations showing the relation of man's concern in making more

intelligent use of the earth's treasures. As has been pointed out, although not all of conservation is science, most of our technological application of wise resource management is the result of the contributions of all of the sciences. The scientist is interested and obligated to furthering human progress and welfare whether in the name of conservation or not.

Some Contributions of the Various Scientific Disciplines to Conservation—

It would be impossible to cover the extensive range of research activity, both past and current, in conservation or closely allied fields. Examples will be used from several of the resource management areas, commonly associated with conservation. Each of these professional fields may be considered combinations or complexes representing several of the more traditional scientific disciplines. Yet, each profession represented is recognized as a scientific technology in its own right.

An interesting resume, although quite superficial, of the development of soil research is related by Dr. George L. Scarseth as follows, "When I started about 1922 to train to become a soil scientist, every PhD candidate stood a good chance of passing his exams if he could set up a hydrogen electrode apparatus and explain pH values in terms of hydrogen ion concentrations or strength of an acid. On his first soils job he was likely to measure the pH values of many things, because he had a new tool. Styles changed; soon soil colloidal behavior dominated the soils literature; then came base exchange and cations absorbed. Someone discovered that phosphorus was not behaving as desired, so phosphate fixation became important; then oxidation—reduction potentials, X-ray patterns, radio-active elements, tracers—all had their day. Yet, there is more to come and the production of technological literature crowds our libraries. I must add that the statisticians also came in, to measure the significance of data." (6) Other excellent chapters follow to show the scientific progress made in understanding the physical, chemical and biological interrelationships of organic matter and the primary fertilizing nutrients—nitrogen, phosphorus and potassium.

Relative to forest management, one might ask, "What is the significance of the science of biology to the role of a forester?" G. S. Allen answers the question in this way, "The forester has many hats, but fundamentally, he is a practicing biologist responsible for growing trees of various species by the millions and utilizing a great variety of climates, topography and soils.—In his role as a biologist, the forester must know his tree species—their requirements for light, nutrients, water and growing space at various stages of their life cycles, their ability to grow in pure or mixed stands, and their reaction to various cultural treatments from establishment to maturity." (8)

As is true with most resources, the primary concern in commercial forestry is to grow the quantity and quality of trees at a cost that will keep the forest industry in business. This calls for biological research, as well as research in marketing economics, and utilization of forest products.

Research in forest biology of special significance in recent years includes (1) studies in tree physiology, (2) analysis of site conditions,

(3) chemical and biological control methods against the ravages of insects and tree diseases, (4) forest ecology, and (5) forest genetics.

Increased knowledge of the physiological characteristics of tree requirements goes hand in hand with developing better site conditions for forest growing species. Forest tree insects and diseases are the greatest enemy of the forest and their effect on growth represents the greatest mortality impact on the forest. A recent biological method of controlling sawfly in Christmas tree plantations is by introduction of a virus destructive to the insect. Research continues on more effective methods of controlling the oak wilt, dutch elm disease, and phloem necrosis. The many dead American elms (Ulmus americana) throughout Indiana are evidence that complete control has not been achieved.

Considering the forest as an ecological unit the forester is by and large fully aware of the disturbing influence of his activities on the forest and its component parts. In writing about "Forest Ecosystems," H. J. Lutz, Yale University, says, "Even before the appearance of man, ecosystems were being upset by changes in the organisms and the environments. Disturbances resulting from activities of the human animal are unique only in their extent and severity. I should like to make it clear at this point that it is not my purpose to personify nature as a kindly, beneficent influence and attribute to her a variety of virtues. I do not concur in the view that to disturb or alter in any way natural forest conditions is to court disaster; in the growing and harvesting of forest crops, disturbance is inevitable and alteration of environment or species composition often necessary. But neither do I find acceptable the view that man can do anything he chooses, that he can safely ignore natural tendencies. Between these two extremes there is a wide opportunity for applying the basic philosophy of working in harmony with natural tendencies." (9)

Forest management as with other renewable resources is based on an understanding of ecology and continuous research in forest ecology is extremely important.

In 1959, the first Central States Forest Improvement Conference was held at Wooster, Ohio. Reports were made on the progress of research in forest genetics from the six research centers in the central states. Although most of the forest genetics research in the central states has been devoted to selection and hybridization, other forest research centers have moved in recent years from empirical to more basic research.

The recent storm of protest over the publication of Rachel Carson's "Silent Spring," in which she condemns the indiscriminate use of pesticides and herbicides has placed the entomologists under a strong conservation spotlight. Not all of their research has been in the area of developing new killing chemicals. Noteworthy of mention here is the biological control method developed by Dr. Edward F. Knipling and his associates in controlling the destructive screw fly which infests livestock in the Southeast. This was accomplished by sterilizing male screw worm flies with radio-active cobalt-60. The sterile males, mating with the females in the native population, nullified their reproductive capacity and

the natural population was eliminated. Now Texas has developed a fly plant which produces 75 million sterile flies a week for use in the Southwest.

Fisheries management and wildlife management are recognized professions that have long been associated with conservation. Certain established principles of wildlife management illustrate the importance of scientific research in providing suitable habitat to maintain our wildlife resources.

The wildlife biologist measures the quality of range of an animal species on the basis of what a given area of land will support. This is called "carrying capacity." The bobwhite quail, for example, must find a combination of crop land, pasture, and forest or brush land within easy daily reach to supply its biological needs since quail are birds of low cruising radius. That means their daily flight seldom extends beyond one-fourth to one-third of a mile. Their annual flight does not exceed three miles from home base. The home range, therefore, must provide all its needs at all seasons of the year. An animal population cannot increase in numbers beyond the limits set by the least abundant necessary factor. Thus, if winter conditions are most critical to supply the needs of a species, these factors set a limit on the carrying capacity.

Another principle related to carrying capacity is explained by Allen as follows: "Carrying capacity may have its most important effect by influencing productivity of breeding stocks of various sizes. In a given area, as the number of breeders increases, the production and survival of their offspring is proportionately reduced—a relationship sometimes referred to as *inversity*. This is not true as long as the population is far below "normal" stocking, but after a reasonable build-up it seems to hold." (10)

An example of this was cited from the state of Iowa where a severe winter of 1936-37 killed a large part of the quail population. Records showed that on this area of several thousand acres, the breeding stock in the spring of 1937 was about one bird to 86 acres. The spring nesting conditions were favorable and by fall the population increased by 457 percent.

The surviving breeding stock the following spring of 1938 was up to one bird per 16 acres, but even though favorable weather conditions prevailed again, the season's increase dropped to 183 percent.

Again, a mild winter favored the survival of a large breeding stock and by May of 1939 there was one quail for every six acres which is considered a heavy breeding population. Yet, the birds were able to accumulate only an 84 percent build-up by fall.

As larger breeding stocks produced more young, it seemed that the environmental limitations reduced the proportion that could survive.

Another meaningful principle involved in the mechanics of populations is referred to as "compensation." This refers most significantly to the interrelationship of various mortality factors. It means that when man fails to take a hunting harvest, nature does it for us. Populations may be reduced by predation, disease, starvation, and other decimating agencies. In other words, when the hunter takes a big crop of game in

the fall, he thins out the population and all other mortality rates decline. Hunting has substituted, or compensated, for losses that otherwise would have taken a larger share of the population during the winter. We do not carry a surplus over from one year to another.

The examples of results of research in the professional fields of soil science, forestry, entomology and wildlife are cited to show that the best use and management of our natural resources is dependent in large measure upon scientific processes. Although not all conservation problems are solved by the physical and biological sciences, it is believed that the scientists working in these research areas should shoulder greater responsibility in making their voices heard in the realm of politics and social organizations.

Ecology and Conservation—

Many of the contributions of ecology to natural resource-use have been mentioned. More significantly, attention should be called to the numerous conservation problems that are man-created and, therefore, should be classified as a part of human ecology. The population explosion, pollution of streams and lakes, our spreading "urban" developments, increasing pressure on land and water areas for recreation, drift of industrial smog over our cities, the safe disposal of atomic wastes, and perhaps not least, the maintenance of the genetic quality of man.

The United States is rapidly changing from an agrarian-centered to a city-centered ecosystem. In the past, conservation has been considered largely a farm problem with primary attention given to reducing erosion, maintaining soil fertility and the management of forests, fish and wildlife. In our race for domination of space, it seems rather paradoxical to spend billions to send a man to the moon while we fail to solve our space problem on earth. It is my belief that conservation has become a far greater city problem than a farm problem. Unfortunately, the average city dweller is placidly unaware of his plight while he tries to find a suitable place to fish in waters he has not yet polluted, and wonders why it takes so long to drive home from the office on traffic-clogged streets resulting from laxity in community zoning and planning.

Dr. Allen (10) raises the question whether man, the creature, will overrun his environment and convert it into a biological slum. Allen continues by saying, "There is ample evidence that a reasonable natural world is the only sanitary environment for a human being or any animal. The nobility of man will be a vain and farcical idea if the earth is to be parceled out until every individual is competing with his equals for a meager share of pure air, clear water, green grass, and cool woodland. When we come to live by bread alone, we will have lost the something that makes us more than creatures." Pearson & Harper (11) say, "The food productivity of the earth could perhaps support three billion persons on the Asiatic standard of living. This is a considerably greater number than the present estimated world population of 2.1 billions (1945). But at the United States standard of living, the present food productivity of the globe could support fewer than a billion persons.

The American community has evolved toward a standard of living far beyond that of most nations. Science, technology and an abundance

of resources have made it possible. Our agricultural scientists indicate that this nation can support an increasing number of people. Do we wish to live by bread alone? Science may find more effective means to solve the afore-mentioned conservation problems but some aspects of our space requirements are non-renewable as, for example, wilderness, unique landscape features in national parks, and habitat for specific wildlife species.

If man is to maintain his heritage, there must be a greater understanding of the human ecosystem. While scientists have worked independently toward solution of resource-use problems there is a great need for better communications. Our technological progress has outraced the evolution of our social, economic, and political processes. This is a basic cause for many of the world's current problems.

The plight of the human race has been stated in a frightening manner by a former physicist at Oak Ridge, Dr. J. H. Rush, who said, "Just as the evolution of enzymes and later of photosynthesis and oxygen metabolism revolutionized the power of living organisms over the environment, so the technology created by intellect is revolutionizing it again. With his machines and processes, man advances his competitive position more in a century than he could in 1,000,000 years of biological evolution. . . ."

"Man, the product of 2,000,000 years of patient protoplasmic experiment, has been on earth only a moment of geological time. Yet he already holds the power to destroy all life, even the planet. Outwardly he shows little awareness of his responsibility or his peril; but the fear is seeping into his bones." (12)

The ramifications of human ecology are complex indeed, compounded by man's intellectual capacity to alter the environment. No one wishes to return to a stone age civilization nor to the life of the early pioneer just to preserve the natural habitat. But there is a scientific, social and economic consciousness that needs to accept the view that we cannot safely ignore the consequences of wasteful exploitation of our land, waters, wildlife, minerals, as well as human resources. This presents a formidable challenge to every phase of human endeavor.

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ANTHROPOLOGY

Chairman: Richard Johnson, Indiana Historical Society

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Post-Glacial Ecology and Prehistoric Settlement Patterns in the Central States Area

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It is only within the span of the last decade, with its break-throughs of nuclear biology, especially the development of refined methods of dating of archeological remains by the radiocarbon method, and the accumulation of such dates for various prehistoric manifestations, that the nature of the ecological relationship of the American Indian to his environment in the eastern United States is beginning to emerge. Earlier attempts to elucidate ecological relationships, such as that by Wissler in 1926 (12) properly pointed out the permissive nature of the environment—rather than determinative nature, as far as man is concerned—were seriously hampered by the lack of a chronological framework for the cultures as well as the lack of information on continuities and possible replacements of populations.

Man is unique among animals in that, by virtue of his culture, he is the least dependent on his environment and with the passage of time he has been able to modify or control it to an increasing extent. This fact makes it exceedingly difficult to point out specific causal relationships and to examine relationships which, ecologically speaking, cover rather limited spans of time. It is therefore at this time only possible to sketch these relationships in the broadest outline in the hope that it will provide a framework the details of which can be filled in with the accumulation of specific data.

The physiographic province under consideration covers most of the central part of the United States—and if we follow Fenneman (4) especially the Great Lakes section and the Central Lowlands east of the Mississippi. The latter comprises local lowlands and uplands and constitutes an area that is being dissected in true plateau fashion. The elevation of the province ranges from 1500 feet on the western edge to 300 feet on the shores of Lake Ontario. To the west it is bordered by the Great Plains which cover 532,000 square miles in ten states, an area that is characterized by its flat-lying rocks. Glaciation dominates most of the landscape.

The province boundary is marked by a visible contrast of topography along its borders. The topographic distinctions in this area depend not so much on underlying rocks as they do on the glaciations. The ice is known to have advanced at least a half dozen times followed by a retreat. Each successive glaciation covered some territory not reached by its successors.

The major glaciations are generally classified as the: Nebraskan (bottom), Kansan, Illinoian, Iowan, and the Wisconsin. The present drift cover falls into three main divisions: Kansan, Illinoian, and the more recent sheets.

The northeastern part of the Central Lowlands is characterized by lakes which are very abundant although they are not evenly distributed. Swamps represented intermediate stages between lakes and dry land, and flat plains bordered the Great Lakes. Much of the area is covered with marginal moraines, outwash plains, and rolling ground moraines—all evidences of recent glaciation. The lowlands, south of the Great Lakes section with its drift areas, reflects the features due to underlying rocks to a much greater extent. The dominant structural features here are the northern part of the Cincinnati anticline which brings Ordovician rocks to the surface, and the southern Illinois syncline, which bed the Carboniferous coal measures. Deeply dissected areas and minor uplands have repeatedly served as refuge areas for Archaic populations.

It soon becomes obvious to anyone who carries on archeological excavations in a number of cultural horizons of a particular area, and studies them in their ecological setting, that the prehistoric remains exhibit considerable differences in settlement patterns as one goes back into time. It can be equally well demonstrated that there was an increase in dependence on the natural resources of the immediate localities inhabited as one proceeds into the past. The dependence is, of course, greatest in the most ancient hunting and gathering groups or those that retained such an economy until historic times mainly because of local abundance of game and fish. With food production, an increase in population, and the expansion of trade, dependence on immediate surroundings becomes less direct, and the nature of population pressure changes.

With the retreat of the last glaciers in the Middle West eleven to thirteen thousand years ago, we note the first shift in economy. The Paleo-Indian hunters gradually shifted from dependence on Pleistocene big game, especially various species of now extinct bison, to hunting smaller game such as deer that spread into the area accompanying a change from prairie to woodland conditions. Concomitant with this change from a Paleo-Indian to an Archaic level we also find a greater dependence, at least seasonally, on the molluscs found in the larger streams.

The Archaic Pattern was followed by a Woodland Pattern with increasing forestation and the development of regional cultural traditions. The Middle Woodland period was characterized by considerable interaction of traditions and the rise of secondary culture centers. Toward its end, corn is introduced to supplement the mixed diet of the hunting and gathering economy, and the emergence of the Mississippi Pattern.

The Mississippi Pattern which developed in the middle Mississippi area represented a marked change in the way of life—a food-producing tradition supporting town dwellers. The proto-historic period, finally, saw a reemergence of the Woodland Pattern and the fusion of Mississippi

and Woodland traditions in several localities, a process that was only stopped by the advent of the Whites and the subsequent displacement of the Indians.

The Paleo-Indian

Given an immediate post-glacial period of 12,000 to 15,000 years, we can thus observe considerable climatic changes accompanying drastic shifts in ecology. With the ecological changes we can trace evolutionary cultural changes that allow certain groups to occupy particular ecological niches.

As Mason has recently demonstrated (7) on the basis of the distribution of Folsom spear-points and other lithic remains attributed to the Paleo-Indian, the earliest hunters occupied the Great Lakes region soon after the retreat of the last glacier. Radiocarbon dates from Wisconsin indicate that this took place around 13,000 B.C. An earlier occupation of the continent by the Paleo-Indian is well substantiated by many radiocarbon dates, which indicate that man was contemporary with a Pleistocene mammalian fauna which includes the horse, camelops, the ground sloth, the mastodon, and a number of species of now extinct bison.

Areas vacated by retreating glaciers pass through a regular sequence of climatic and ecological zones during the course of several thousand years as the temperature rises. At first tundra conditions prevail. Gradually grasses begin to cover the flat, barren, lake-studded land. Arctic forms of mammals prevail. During the Sangamon Interglacial Period even musk oxen roamed as far south as central Illinois. (8) As northern Indiana became swampy around 10,000 years ago, herds of mastodons seasonally wandered north for forage. Their remains are frequently encountered in ancient peat bogs, one of which has recently yielded a human skull of an early mastodon hunter. These mastodons were hunted in the West from Wyoming to the Valley of Mexico. One find in particular from Wyoming has been described as a hunting camp where one of these animals has been killed. Undoubtedly the Paleo-Indian followed the mastodons into the Great Lakes area. Mason recently suggested that the early hunters, who made the fluted points which are part of the Paleoeastern culture, entered the Lower Peninsula of Michigan about 11,500 years ago from Indiana and Illinois, following closely on the retreating margins of the Cary ice. From the scattered remains a slowly changing hunting culture is indicated. Mason emphasizes the fact that the fluted points are definitely not a trait of the eastern Archaic cultures, but part of the Paleoeastern complex that ceased to exist by the time that recognizable Archaic manifestations had developed. His distribution maps of fluted spear points clearly demonstrate that they are limited to the southern half of the Lower Peninsula, the northernmost finds having been made in a tier of counties west from Saginaw Bay across the state. This strongly suggests that the Paleo-Indian occupation of the lower part of the state was contemporaneous with the glacial cover of the northern half of the peninsula.

The Archaic Period

Sometime around 8000 B.C. with changing ecological conditions and forestation of formerly glaciated areas an Eastern Archaic culture began to differentiate. During the Terminal Glacial retreat between 6000 and 3000 B.C. the climate changed from a damp cool to a warm dry climate (10). Pines achieved dominance during the first part of the period, and were followed by an expansion of great grasslands, which spread eastward across the area as far as New York state. After 2000 B.C. the climate became cooler again and conditions had become much as they are today. The mastodons had left the region and deer and elk replaced the barren-ground caribou. The period of a seven thousand year duration reflects various adjustments to a mixed hunting and gathering economy within a woodland ecological setting.

In many parts of the world populations, now living in larger aggregations, seasonally supplemented their diet of small game and wild seeds with shellfish. Large shellheaps found along the shallows of the majority of larger streams throughout the Middle West and the South attest to the extensive use of clams for food. The fact that the people of this period often seem to have been malnourished and undersized and their cultures of low vigor has led Jensen (6) to suggest that grave thiamin deficiencies from the destruction of thiamin by thiaminase of shellfish may be the reason. The enzyme in these foods is destroyed by cooking, which is known to have been practiced at that time because of the presence of hearths with fire-cracked rocks used in "stone-boiling."

By studying the remains found on Archaic sites it can be inferred that the people certainly lived in family groups or bands up to about fifty individuals leading a migratory way of life in pursuit of game.

Winter (2) describes this seasonal shift from one riparine camp site to another as follows: "As the seasons changed they moved from camp to camp, taking advantage of various natural resources, both plant and animal, or seeking shelter in inclement weather. Thus, were we able to follow a typical band throughout the year, we might find them during the fall in a camp near a grove of nut trees. After their departure from this camp, the ground would be left littered with the pebble grinding stones, pestles, grinding slabs, and nutting stones which had been used in preparing the harvest of nuts and other ripe seeds for consumption and storage. The winter would perhaps be spent in a rock shelter, where campfires placed towards the front of the shelter would warm the interior both directly and by heat reflected from the rock above. There would be innumerable fragments of burned sandstone or other rock scattered around the hearths, since throughout the year stone boiling was a standard procedure for cooking food. That is, stones were heated in the hearths and dropped in the skin or bark food containers. Part of their food would be supplied from the fall harvest which had been stored in pits in the floor of the shelter. Deer and other game would have formed another part of their diet, since hunting was very likely a year-round activity. As always, there was need for chipping dart and spear points and making other stone tools. Perhaps time was also spent in making the beautiful tools of ground stone which

have been found on so many Archaic sites in Illinois. With the coming of spring, open campsites would again be reoccupied for the gathering of edible plants and roots. In the following months, the camp would move from time to time as game was depleted in the area and as new food sources become available in other areas. With the fall, we should again find our band at its site near the nut groves, completing its seasonal round." (pp. 9-10.)

It was towards the end of the early Archaic period, perhaps around 6000 B.C., that inhabitants of the area learned to utilize their woodland environment. This corresponds to Caldwell's (3) first economic level. In a recent paper he demonstrates that there have been three dominant trends in the prehistory of Eastern United States which lead to three stages or economic levels: (1) the establishment of primary forest efficiency, (2) the dominance of regional differentiation and stylistic change in artifacts, and (3) increasing connections with Nuclear Middle American civilization. The first two transformations, which had been completed at the time of European contact, depend to a greater or lesser degree on ecological conditions prevalent at the times the particular cultures existed. All evidence points to a very slow cultural development during the Archaic period, and emphasizes the fact that a culture must have advanced to a certain level before proper utilization of particular ecological resources can take place. Despite a greater concentration of population and living in villages, the Archaic people had to await the advent of pottery, food production (corn, beans, and squash) and a more complex socio-religious organization that served as a cohesive factor, before undergoing a radical change in the way of life typical of the more advanced Neolithic agricultural town dwellers. In northeastern North America the innovations were adopted in the Terminal Archaic after 1000 B.C., which allowed the Archaic groups to become gradually identified with the Woodland culture.

The Middle Woodland Period

As mentioned in the preceding section, the onset of the Woodland period was gradual, varied with the locality, and lasted as the Early Woodland period over a span of two thousand years, that is, from 2500 to 500 B.C. Archaeologically the Woodland sites can be recognized by the presence of pottery, generally sherds of conoidal vessels with cord-marked or stamp-decorated surfaces. Evidently at least two ceramic traditions developed, the northern remaining relatively unchanged, while the southern or Mississippi tradition became quite distinct. The ultimate origin of the Early Woodland pottery has not been ascertained, for some hold that it is a local development, while others have attempted to trace it to northeastern Siberia.

The Middle Woodland Period is distinguished by an elaborate assemblage of traits of the Indians of the widespread Hopewell culture, which flourished in two centers between 300 B.C. and 500 A.D. The center in the Illinois River Valley yields radiocarbon dates that are somewhat earlier than those from the center that was located in southern Ohio (2, p. 21).

Struever (11) especially has been greatly interested in the ecological relationships of the Middle Woodland peoples. Whereas the Early Woodland (Black Sand Focus) people of the Illinois Valley, who are directly ancestral to the Hopewell group in that area, invariably occupy river bottom sites which were located right on the river bank, often on sand bars, the Middle Woodland peoples generally occupied higher ground, which has been characterized as bluff-base occupation. This suggests canoe nomadism for the former, and a sedentary occupation for the latter. The Middle Woodland Hopewellian groups are well-known for their erection of earthworks and burial mounds. So far no evidence for the cultivation of maize has been discovered in Hopewellian sites in Illinois, though the fact that one finds a concentration of population in large villages around the ceremonial earthworks and burial mounds strongly suggests food production. Struever believes that even the Classic Hopewellians still maintained a hunting and seed-gathering economy. As proof he discovered remains of large quantities of pigweed *(Chenopodium)* seeds in cache pits. Nuts, berries, roots also made up an appreciable percentage of the diet. Chief dependence was still on the Virginia deer and a number of smaller mammalian species. Rabbit bones are noteworthy because of their absence—a fact that may have some connection with a mythological role the rabbit plays in trickster tales of the Algonquian tribes. We thus have a hunting-oriented culture which nevertheless congregated in fairly large population assemblages for socio-religious reasons, which was only possible in favorable, rather restricted environments. Struever points out that it was in the riverine alluvium, along the mud-flats bordering sloughs and river banks that presented just such density and diversity of natural food products, and Caldwell (3) holds that it must have been under just such conditions that the earliest cultivation was practiced. Subsistence thus restricted the concentration of people to the broad river valleys along which we indeed find the greatest population expansion of the Hopewellian period. There is little doubt that horticulture, that is food production, and the actual introduction of the maize plant was from the south.

An elaborate mound burial complex in which the ruling families were buried in specially prepared mound tombs while ordinary people were buried or cremated (Ohio), indicating a socio-religious cohesive factor; artifacts and materials demonstrating extensive trade and far-ranging contacts; and the increase in cultural complexity and elaborateness of ceremonialism and settlement pattern in a series of ecological zones—all raise interesting questions regarding the relationship between subsistence patterns and particular ecological niches.

According to McGregor (2, p. 24) the Classic or Late Middle Woodland people had maize and practiced limited agriculture. Be that as it may, in general the Middle Woodland peoples represent a cultural peak in the prehistory of the area, and a way of life that led to the development of extensive permanent settlements.

The Middle Mississippi Tradition

It is now the consensus of archaeologists that the Middle Mississippi cultural tradition is an outgrowth of the Woodland Pattern with its

regional traditions. The interactions of a number of these regional developments, near the mouth of the Missouri and in the Tennessee-Cumberland area, led to the emergence of a culture that was primarily agricultural but centered around towns. These towns, which served as religious centers, furnished the necessary cohesion. The earliest developments probably date back as far as A.D. 500 with good-sized villages by 900, and the climax of well developed religious centers between 1200 and 1450. An analogous development of politico-religious centers and daughter colonies occurred in the South.

Practically all of the towns with their temple mounds, chief's mounds, and town squares were established in areas with like climatic conditions, such as found in northern Mississippi and western Tennessee. They were in areas with a warm humid climate and a long growing season, with winter temperatures that rarely fall much below freezing. The palisaded towns were found along the main river courses where cane, pecans, and cypress grew. Intense cultivation of the soil was carried on by the farmers in the river bottoms surrounding the towns. Although there were no definite streets, the square wattle-and-daub houses with their grass-thatched gabled roofs were oriented with their corners to the four cardinal points. Grass-lined storage pits for corn dotted the whole site within the stockade.

Subsistence was based on growing maize, beans, and squash, supplemented by game (deer), fowl, and fish. Camp refuse from such sites yield reliable information about food habits and species of animals utilized for food, as well as approximate proportions of plant food to game and fish (1, 8, 9). It has been estimated that the larger centers may have had between 1000 and 2000 inhabitants and a population that may have increased in times of festivities or times of danger when the farmers of the surrounding countryside would flock to the towns. Such a concentration of a sedentary population probably let to an exhaustion of local resources, for we find that most of the towns seem to have a rather brief occupational history. Most of the settlements were contemporaneous, for there was wide trade, and such uniformity in settlement pattern that Indians from a thousand miles away would know what to expect in the settlements.

The Historic Period

The mode of life and ecological relationships of the historic tribes corresponded roughly to three ecological and culture areas. In the northeastern Woodlands and eastern Canada the tribes belonged mainly to the great Algonquian linguistic family. Tribes such as the Menomini, Potawatomi, Ottawa, Chippewa, Miami, Illinois, Shawnee, and Delaware were the descendants of the Boreal Archaic and Early Woodland peoples, native to the area for at least five thousand years. They were adapted to a hunting economy in a northern forest environment. Food production was secondary and the growing of maize directly dependent on the length of the growing season. The densest populations were found in the river valleys and lake regions, in locations where forage was most plentiful for deer. Transportation was by birch-bark canoes, and settle-

ments, consisting of an aggregation of bark or mat-covered wigwams, were invariably located immediately on the banks of streams.

Similarly, in the South, the tribes had been indigenous to the area for seven thousand or more years, again derived from an Archaic (Southern) population. The linguistic homogeneity—most of the tribes spoke languages of the Muskogean linguistic family—is attested by the continuous block of related languages, revealing very little of the shatter pattern characteristic of marginal populations. Tribes such as the Chickasaw, Choctaw, Creek, Seminole, and the Iroquoian-speaking Cherokee are typical. Their culture was largely of the Mississippi Pattern, largely food producing, and, as previously described, centered in towns. Since the Indians never had draught animals and the plow to cut the hard soil, settlement was largely limited to the fertile river-bottoms where the soil was tilled with digging sticks and flint hoes. It has been estimated that maize, beans, and squash formed about seventy percent of the diet. It was supplemented by game (mainly Virginia deer), fowl, and fish. Transportation in contrast to that of the north-eastern Woodlands was by dug-out canoes. The towns, as described for the Middle Mississippi period above, were palisaded and located along the main river courses.

The third major culture area that impinges on the Middle Western region is the Plains area, where subsistence was based chiefly on the hunting of the bison. Linguistically, the Indians of the area were largely Siouan-speaking. The expansion of the Southern Village Indians, who grew maize, occurred mainly between A.D. 1100 and 1300. The movement from the St. Louis area was largely directed up the Missouri, Mississippi, and Illinois rivers. Tribes like the Wichita, Caddo, Pawnee, and Arikara were Caddoan-speakers and still formed linguistic islands along the Missouri in historic times, after being engulfed by the Siouan tribes that spread from southwestern Minnesota and the eastern Dakotas to the southwest across the Plains. The Teton, Brulé, Ogalala, Yankton, Kansa, Osage, Iowa, Missouri and Winnebago are the best known. Subsistence, in the contact period, was almost entirely based on hunting of the bison. But there is good evidence (5) that the large herds of *Bison bison* are a rather recent development, perhaps since 3000 B.C. The Siouan expansion into the Plains dates largely after 1300, and is closely related to the advent of the horse (1540-1740), which gave these tribes greater mobility. Some bison ranged over northern Illinois and northern Indiana and were hunted by the Sauk and Fox and the Winnebago Indians, who introduced Plains area customs into this section of the region under consideration. Archaeologists have been able to trace this historic eastward movement by the presence of Oneota (Iowa) pottery and skeletal remains which definitely points to Siouan influences. It must, however, be kept in mind that this only represents a historic movement, rather than a long range adaptation to ecological conditions.

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A Comparison of Crania From the Shell Heaps of Brazil With Those of the Archaic of the Eastern United States

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It is now generally accepted that sometime previous to 8000 B.C., a culture adapted to open forest conditions, began to differentiate in the eastern portion of North America. This culture, which became known as the Eastern Archaic, was based on earlier Paleo-Indian traditions, and since it was carried by relatively small bands of people, differentiated into a number of local cultural manifestations, and, as genetic isolates, into a number of local physical types. Yet, undoubtedly contacts of a sort were maintained, so that despite the cultural and physical diversification, two fairly distinct branches developed. These represented adaptations to broad climatic and ecological areas, and exhibited enough cohesion to become associated with large linguistic entities. In the northern area, more recently vacated by the retreating glaciers, we thus find a Boreal Archaic culture, largely associated with a Lenid (rugged eastern long-headed) variety, (1) and consisting of groups which were in all probability speakers of Proto-Algonquin. In the southeastern part of the United States the Boreal Archaic was matched by the Southern Archaic culture, associated with the Iswanid (small southern mesocranial) variety, consisting of populations which in all probability were Proto-Muskogean in speech. There is some evidence that three or four thousand years later the linguistic stocks had fairly well differentiated, and that a number of Paleoamerind varieties had made their appearance.

A possible third linguistic stock, the Siouan, probably also occupied parts of eastern United States as early as the Late Archaic, possibly occupying the intermediate area, via the Ohio Valley, between the Mississippi and the Eastern Seaboard. Physically, these people were probably more closely linked with the Boreal Archaic culture and the Lenid variety in the East, and with the Southern Archaic and Iswanid variety in the Middle West. But as yet these relationships are still somewhat conjectural, being based for the most part on the fact that eastern Siouan groups exhibited Woodland traits, and that physically they antedate the Dakotid variety of Siouan-speakers west of the Mississippi. The long-headed, high-vaulted Mandans, traditionally the ancestral group of the Siouan-speakers, are also physically the closest relatives of the Siouan tribes of Virginia, while the intermediate Quapaw of Missouri—also non-Dakotid physically—suggest an Iswanid link with the Southern Archaic.

The problems involving the Eastern Archaic are thus definitely relegated back to the period around 4000 B.C., a period during which grasslands spread over an area that extended from what is now Illinois to the Atlantic coast. In general it may be said that the Eastern Archaic culture over a period of seven or eight thousand years reflected a series

of adjustments of a hunting and gathering economy in a woodland setting.

Going farther afield, to the Southwest, and to a number of South American areas we find similar adjustments and transitions from Paleo-Indian to Archaic level cultures which exhibit general parallels, but differ in specific culture content. A number of archaeologists recognized this North and South American parallelism, but were reluctant to go farther than to point out parallels that could be expected in a general Archaic level of cultural development.

When Professor Georg K. Neumann of Indiana University read the manuscript of Willems and Schaden *On Sambaqui Skulls* (2) previous to its publication in 1951, he noted close morphological resemblances of this material to the Archaic Indian Knoll people of Kentucky, and on that basis suggested a closer metrical and morphological comparison to determine possible physical relationships of these two series. Since the morphological observations are not strictly comparable, the present study confines itself largely to a metric and indicial comparison in the hope that it will reflect morphological similarities. As the Sambaqui series is quite small this study is to be regarded as a preliminary or pilot study for more detailed work, which would necessitate a reexamination of all Brazilian material under conditions in which standardized morphological observation techniques are employed. The series described by Willems and Schaden, although limited, nevertheless points out the basic similarities of these two populations, and shows where the greatest differences exist. These differences may be interpreted either as a matter of genetic drift or minor adaptations to local conditions.

Interest in the ancient peoples of eastern Brazil dates back to Lund's excavations of the Lagoa Santa crania from the Sumidouro caves between 1835 and 1844. Subsequently the sambaquis or shell heaps from the southern coast of Brazil yielded cranial material which has been repeatedly identified as representing a second Paleomerind variety. The first description of sambaqui material was published by Lacerda in 1882. A larger series, which included Lacerda's material, was later reexamined by Willems and Schaden (2) and serves in the broader comparisons made in this paper. The Archaic Indian Knoll series from Kentucky is that which is part of the collections of the U. S. National Museum. Observations and measurements on this series were made by Professor Neumann, who describes the Iswanid variety which it represents, as follows: (3) "The skull is relatively small with an average capacity of 1366.9 cc., a cranial module of 150.4, a glabello-occipital length of 177.0 mm., a maximum breadth of 134.9 mm., and a basion-bregma height of 138.8 mm. These dimensions yield a cranial index of 76.25, and a length-height index of 78.27. The cranial vault is therefore on the lower border of mesocrany and high in relation to its length. It is ovoid in form, with medium muscular relief, small to medium brow ridges, medium frontal slope, small frontal breadth, a slight amount of sagittal cresting, medium parietal eminences, only a slight amount of lambdoidal flattening, and an occiput that has a medium high position.

"The face as a whole is of gracile rather than rugged build and not large in relationship to the braincase. All facial dimensions tend to be moderate (total facial height 118.0 mm., upper facial height 70.1 mm., and bizygomatic breadth 135.9 mm.), and the same applies to the proportions of the face (total facial index 87.09, mesoprosopic, and upper facial index 52.14, mesene). The size of the zygomatic bones and their anterior projection are only moderate, but the lateral projection of the zygomatic arch is generally pronounced. The orbits are most frequently somewhat oblong, often square with a small amount of inclination; and the (left) orbital index is mesoconch (77.92, if the breadth is taken from maxillofrontale, 88.33 from dacryon). The nasal index is leptorrhine, 46.60, on the border of mesorrhiny. Absolute diameters of the nasal structures are small with a breadth of 23.8 mm., and a height of 51.2 mm.; both root and bridge dimensions are moderate. Prognathism is medium to submedium. The size of the mandible is medium, the most common chin form is bilateral, and gonial eversion small to medium." (3)

A comparable description of the Sambaqui skulls, following Willems and Schaden, would be as follows: The skulls are of medium size, with an average cranial capacity of 1442.4 cc., and a cranial module of 151.7. The glabello-occipital length is 177.4 mm., the maximum breadth is 138.0 mm., and the basion-bregma height 137.5 mm. These dimensions yield a mean cranial index of 78.42, and a mean length-height index of 77.76. The braincase is mesocranial, and high in relation to its length.

Judging from a few photographs, it appears that the skull is ovoid in form, with medium muscular relief, medium brow ridges, medium frontal slope, occasional sagittal cresting, medium parietal eminences, little lambdoidal flattening, and an occiput that has a medium high position.

In facial dimensions and proportions the Sambaqui skulls are moderate, with a rather short total facial height of 112.6 mm., a moderate upper facial height of 72.5 mm., and a bizygomatic breadth of 138.0 mm. These dimensions yield a euryprosopic total facial index of 84.43, but a mesene upper facial index of 54.45. The size of the zygomatic bones and their anterior projection are moderate, but their lateral projection is generally marked. The orbits tend to be square and rather high with a breadth of 40.4 mm., a height of 36.0 mm., and an orbital index of 88.75. The nasal breadth is 26.5 mm., the nasal height 51.3 mm., and the nasal index 51.61, on the border between meso- and chamaerrhiny. Both root and bridge dimensions and prognathism tend to be moderate. The size of the mandible is also moderate, the most common chin form is bilateral, and gonial eversion is generally lacking.

If these two descriptions are compared point for point, the general similarity of the Eastern Archaic and Sambaqui populations is striking. Over-all cranial size is moderate for both; they are similar in vault form and dimensions, both being mesocranial and hypsicranial. The shorter faces of the Sambaqui population center mainly in the symphysial height of the mandible rather than in differences in upper facial height. Orbits tend to be definitely higher in the Brazilian series, which is also characterized by somewhat broader nasal dimensions, at least as far as one can determine from six cases.

In summary, this paper provides the morphological and metrical proof for Professor Neumann's suggestion of near identity of the Eastern Archaic and the east Brazilian Sambaqui populations, which, if roughly contemporaneous, and separated only for a relatively short time span, should show a considerable degree of resemblance. These resemblances in turn might suggest other historical relationships which deserve to be tested.

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Preliminary Notes on the Pelvic Floor Musculature of Macaca ira in Relation to the Assumption of Upright Posture[1]

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With the advent of the fixation of the body for extensive use of the hands and of true upright posture, the bony pelvis and the muscles of the pelvic floor have undergone certain morphological changes for the support of the pelvic viscera. The form of the pelvis and the arrangement of its muscles in most pronograde mammals would offer little support for the abdominal viscera were the animal to take the upright position for brachiation or extensive hand use, not to mention bipedal progression.

In the primates there are obvious differences in posture and in the morphology of the pelvic bones and pelvic floor musculature. Although they are end products in their own evolutionary sequences, the individual primates at their different levels of developmental sophistication suggest factors present at various stages in the phylogeny of the primates as a group. Because of these indications, Sir Arthur Keith (4) and others have suggested that a comparative study of the pelvic floor musculature of the primates may give us more knowledge of the evolution of this muscular diaphragm which is so important in the assumption of upright posture.

Following this premise, H. O. Eggeling in 1896 (1), outlined a general evolutionary pattern for the pelvic floor in the higher mammals. In turn H. O. Elftman in 1932 (2), synthesized Eggeling's comprehensive work and suggested a more specific scheme of evolution for the pelvic floor muscles in primates from data obtained from dissections of the following species: *Lemur rufifrons*, *Tarsius*, *Papio*, *Lasiopyga*, *Cebus*, *Hylobates*, *Pongo*, *Pan*, *Gorilla gorilla*, and *Homo sapiens*.

To summarize Elftman's theories, it is necessary to point out that the posture of the primates ranges from the pronograde lemur to the true upright bipedal gait of man. The stages in between are represented by the sitting of the Old-World monkeys and the brachiating and sometime bipedal progression of the Great Apes. In none of the postures illustrated is there as much pressure and strain induced by the viscera on the pelvic floor outlet as there is in the fully erect walking of man. For here, the shock of each step is transmitted by the jarring of the abdominal contents toward the pelvic floor.

To sustain this strain, the shape of the pelvis has come to play more and more of a role in visceral support by becoming more "basin" shaped—i.e., the pelvis is flattened downward and expanded laterally and antero-posteriorly. Further bony support in man is provided by an inward curving sacrum placed at the level and below the symphysis pubis—thus differing from the highly placed and rather straight sacrum

1. The author expresses his appreciation to Dr. Riggins of the Pitman-Moore Biological Laboratories who donated the specimens used.

of the other primates. These changes in the pelvic bones are correlated with upright posture.

Although the bones of the pelvis in man offer relatively more support, there are still many areas of the floor and diaphragm that are totally unprotected and unsupported by bone. The muscles that are found in these areas are: the tail muscles—the coccygeus, pubococcygeus, and iliococcygeus; the muscles of the urogenital triangle—the bulbocavernosus, ischiocavernosus, and the transversus perinei; and the anal triangle muscle—the sphincter ani externus.

In the lemurs and Old-World monkeys—the first mentioned group, the pubo-iliococcygeus muscles—exhibit considerable development because of extensive tail use. In addition the pubococcygeus becomes more closely related to the rectum—progressing from the lemurs to man. In the anthropoid apes and man the absence of a tail sees the iliococcygeus becoming tendinous with only the pubococcygeus retaining a muscular form and supporting function. In modern man the iliococcygeus and coccygeus tends to be even more tendinous and fascia-like. Elftman concludes that with upright posture the increased resiliency and resistance to fatigue of fascia structures facilitates a withstanding of long periods of stress.

In the urogenital area from the lemurs to the anthropoid apes the fibers of the bulbocavernosus muscle strengthen the diaphragm by inserting on the ischial bones. In man, on the other hand, a separate muscle—the transversus perinei profundus joins the ischial bones and is separated from the bulbocavernosus by fascia.

In all non-human primates the anal triangle muscle, the sphincter ani externus, is much heavier than in man. Furthermore, in the anthropoid apes this muscle has migrated and spread from the anus to the pubic symphysis, adding support to the urogenital diaphragm. In man the sphincter ani externus is located around the anus, and the transversus perinei profundus, in turn, adds support to the urogenital area of the perineum.

Elftman's general conclusions from his study on the evolution of the pelvic floor muscles are: [1] that the supporting function of the tail muscles (iliococcygeus, pubococcygeus, coccygeus) is already present in the Old-World monkeys, as is a more active support of the viscera by a slight funneling of the bony pelvis; [2] that the muscles which cease to be for tail movement become tendinous and fascia-like; [3] that the shape of the human ilium is correlated with erect posture; [4] and that the "new" muscle, the transversus perinei profundus in man replaces the fibers of the bulbocavernosus which go to the ischia in the Old-World monkeys and replaces the spread-out sphincter ani externus in the Great Apes.

Elftman's postulates suggested the present study of an Old-World monkey. The dissection of Papio (the baboon) and Lasiopyga (the Mona monkey) make up the totality of the data on his study of the Old-World monkey. From this work he concluded that a common ancestor of the Great Apes and Man could have been in many aspects, as far as the muscles of the pelvis are concerned, similar to a typical Old-World monkey. In other words, he believes that the state of the pelvic floor

muscles in the monkeys is such that it could easily serve either a "primitive brachiator" or an "incipient biped".

His theory thus suggests that variation studies on a genus of unspecialized Old-World monkey would shed further light on pelvic floor evolution in the primates—for Elftman based his conclusions on data from two relatively specialized forms: Papio, the predominantly terrestrial baboon and Lasiopyga, the arboreal Mona monkey. Since two extreme types of Old-World monkey have already been investigated, it seems that a study of a more generalized specimen of this group would be more profitable.

The choice of *Macaca ira (Cynamolgus Irus)* fulfilled most of the prerequisites. Irus is a hardy, rather small, monkey from South-East Asia and India (5). Furthermore, this species was selected for study because of its availability, extensive use as a laboratory animal (3), and for the important fact that hardly any morphological investigation had been previously carried out on it.

The general purpose, then, of this investigation of Irus was to carry out a morphological study of the muscles, and to obtain a sufficient sample of variation to contribute to our knowledge on the evolution of pelvic floor musculature in primates.

In Irus the upright position is maintained mostly while sitting during fixation for extensive hand-use and for climbing, with more extensive progression accomplished in a modified pronograde position—i.e. with the body inclined to the rear because the arms are longer than the legs. *Macaca ira* has a long, narrow pelvis in relation to its width with relatively flat, vertical ilia; in addition the sacrum is placed much higher relative to the pubic symphysis. As is the case in most Old-World monkeys, this species has ischial callosities for protection of the pelvic floor outlet while sitting. As one would expect, because of the relatively little bony support to the abdominal contents, the strongly developed tail muscles also serve a supporting function. The ventral part of these muuscles (the pubo-iliococcygeus group) have some insertion into the viscera, notably, the pubococcygeus sends fibers to insert into the rectum. Like most species of primates there is some sexual dimorphism present in the form of the muscles of the perineum. In the male the bulbocavernosus and ischiocavernosus are well developed with the converse being true in the female of the species. The female shows the most interesting variation in this area and in the associated sphincter cloacae.

In addition to a more complete morphological study the following is observed in the variation investigation: [1] the degree of association and insertion of the pubococcygeus muscle into the rectum; [2] the degree of tendonization and fascia formation of the three large and important tail muscles—the iliococcygeus, pubococcygeus, and coccygeus; [3] the problem as to whether the bulbocavernosus inserts fibers to the ischial bones and how such an insertion is arranged; and finally, [4] the degree of migration of the sphincter ani externus.

In conclusion, the research has progressed to the point that a general morphology of this area of Irus can soon be completely drawn up; and all that remains is for a greater sample to be taken in the

variation study. However, the pilot study has revealed certain trends; and the following results can be expected: In all the specimens of the sample varying degrees of muscular insertion of the pubococcygeus into the rectum was found. Secondly, the largest percentage shows strong muscularity for the pubo-coccygeus group. If tendonization is present, it is usually in the iliococcygeus and coccygeus, rather than in the pubococcygeus. Next, the degree of variation of the bulbocavernosus may suggest whether the transversus perinei profundus in man can be considered its homologue. Only a large sample can give significant data for consideration of this problem, however. Finally, the sphincter ani externus doesn't seem to have a wide-spread migration in Irus.

Preliminary studies of the migrations of the bulbocavernosus and sphincter ani externus would tend to indicate that man and the Great Apes developed from a common Old-World monkey-like ancestor with the development of the transversus perinei profundus coming from the migratory bulbocavernosus. This, plus the increased tendonization of the great tail muscles seems more sensible than to postulate a loss of an ape-like sphincter ani externus in the forms leading to man.

The fairly good size sample of thirty specimens should yield, when fully investigated and processed, sufficient data for support or rejection of the postulates thus presented on the evolution of the pelvic floor musculature in primates.

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The Incidence and Age Distribution of Osteoarthritis in an Archaic American Indian Population

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This investigation deals with osteoarthritic conditions in one of a series of five prehistoric American Indian populations living under varying ecological conditions. It forms a sequel to a paper describing a Middle Mississippi series presented last year at the Anthropology session of the Indiana Academy of Science meetings.

Although the Archaic series from Modoc Rock Shelter is very limited in the number of adult individuals that exhibit osteoarthritic changes, it nevertheless furnishes an indication of the incidence of the disease covering a time span from 3325 to 2765 B.C.

The Modoc Rock Shelter is located south of St. Louis, in Randolph County, Illinois. About 12,000 B.C. the Midwestern climate became warmer and the great continental glacier started its last retreat. The edges of the Modoc Bluff were exposed when the torrents of the Mississippi River began to subside and the river shrank into a smaller bed. The hunters found that the overhanging bluff protected them from rain and snow, and family groups used the shelter until time for the next seasonal migration.

Dr. Winters (8) has written that the climate was much damper and cooler than it is now, when the peoples of the Archaic culture first appeared in this area. The climate gradually warmed until around 4,000 B.C. it was much warmer and drier than today and the great grasslands spread. The climate cooled again after 2,000 B.C. and by 1,000 B.C. had become similar to the present. The ecological setting was a woodland which supported a mixed hunting and gathering economy.

C_{14} analysis has shown the total span of occupancy at the Shelter to be almost 10,000 years. Most of the skeletal material inspected came from the Medial Archaic zone.

No great mammal bones were found since these creatures had moved north or westward. The families which did not pursue them (1) had to learn to hunt deer, elk, racoon and opossum instead. From the river they obtained mussels, snails, turtles and fish. The women dug for wild tubers and collected edible greens. Milling and nutting stones indicate that wild seeds and nuts were also utilized (2). These foods may not have been abundant however since only a small number of these artifacts were found. Marshes and ponds must have attracted the hunters as bones of such migrant birds as the Canada Goose, Snow Goose, Mallard and other ducks were found. Ford (3) mentions that Modoc man had more and better tools but grew no crops.

Bearing in mind a question which followed last year's presentation, the writer has observed that these peoples of basically related populations consistently showed only slight involvement of cervical vertebrae with the main lipping and osteophytic deposition occurring in the lumbar region.

Studies by T. D. Stewart (6) recorded the distribution of arthritic lipping throughout the vertebral column in three racial groups: Eskimos, Pueblo Indians and Whites. He combined the two sexes and all adults over 40 to give groups of 177 Eskimos, 83 Pueblos and 104 Whites. The general pattern showed an increased amount of lipping from above downward in the cervical, thoracic, and lumbar regions. Variations in the amount of lipping in these three areas occurred in these racial groups. The Eskimos had little lipping anywhere but in the lumbar region. The Pueblos had a little more lipping in each area. The lower cervical region had maximum lipping in the Whites, with lumbar and thoracic locations following in this order. The mobility of these joints is determined by racial structural variations of the vertebral column. He concludes that this pattern of racial variations may also reflect differing cultural factors.

Roche (5) found a slightly higher incidence in whites than in Negroes, in older skeletons and in females. In older males however, the incidence equally or exceeded that of the females. His series of 419 vertebral columns of American whites and Negroes (20-99 years) was from the Terry Collection.

In modern whites lipping does not occur often under 30. When it does appear earlier indications of back injuries are also present (7).

Trauma is given as one of the most obvious of all causative agents by Hollander (4). He says, "the wear and tear of the environment leaves its mark on the individual. It might even be said that the process of receding youth is one of unrelenting discovery of areas damaged during the lifelong encounter with the environment."

Last year the same scale of assessment was used as that employed in this Modoc Rock Shelter material:

Stage I—is characterized by slight lipping at the superior and inferior margins of the bodies of the vertebrae, or other joints,
Stage II—exhibits a more pronounced degree of lipping,
Stage III—is characterized by extensive lipping often resembling a mushroom-like eversion,
Stage IV—exhibits bony spurs or bridges with an increased mushroom-like outgrowth,
Stage V—presents actual ankylosis or bony union between two or more vertebrae, or other bones.

Dr. Georg Neumann[1] made the age determinations of this skeletal material using such criteria as endocranial suture closure, dental attrition, epiphyseal union, and, when available, changes in the pubic bone.

The Modoc Rock Shelter specimens available came to a total of 26 individuals, 14 males and 12 females. The estimated ages ranged from pre-adults (under 21) to 72 years. One of the only two individuals not showing any arthritic involvement was a male, age 15. The two other youths showed slight lipping at the margin of the centrum of the

1. The guidance of Dr. Neumann of Indiana University in the work on these series is greatly appreciated by the author.

lumbar vertebrae and were classed as Stage I. The two under-age females were also in this stage of incipient osteoarthritis.

Of the rest of the male population, only one, age 28, was free of vertebral lipping. One in his mid-thirties had Stage II development. Five in the fourth decade had a distribution of four in Stage II, one in Stage IV. Actual vertebral ankylosis, Stage V, was represented by one 66 year old male and two judged to be 70 years of age.

Among the females, the older ones were aged at 65 years having Stage V, and a 72 year old in Stage III. The four specimens in the mid-forties showed a range of Stage II, III, and two in Stage IV (bony spurs). This was slightly more involvement than the male of comparable age. The sole representative of the third decade was a Stage II. Two females in the late twenties were Stage I and II. As mentioned previously, the only male in that range had no arthritic involvement at all.

The sparse sample for comparison shows that the women in the "middle age" range had more extensive osteoarthritic involvement than the males in this range. However, the most striking case of lumbosacral lordosis and ankylosis (Stage V) was in a male whose age was judged to be 70 from dental estimates, bone texture and cranial suture closure. The fact that one individual of the series of Medial Archaic people exhibits a case of extreme involvement in which practically the whole spinal column has ankylosed, indicates that the disease was as prevalent among these Indians in Archaic times as in historic Indian groups.

The writer feels that osteoarthritis of the vertebral column constitutes a prevalent concomitant of age. The incidence of osteophytic lipping would probably agree fairly closely with that found in other Archaic populations if our sample were statistically adequate.

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The Relationship of Cephalic to Cranial Measurements in an Unmixed Group of American Negroes

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When a physical anthropologist measures an individual his thoughts often turn to the bone structure that underlies the flesh. The anatomist, the surgeon, and the artist may have similar thoughts, however, there is little statistical data available to substantiate or reject any projection they might make as to the correlation of the living measurements with those of the skeleton. Only rarely are standardized measurements available in both the living and skeletal conditions for the same series of individuals. For this reason the present preliminary study was made using the cranial and cephalic measurements obtained from a group of American Negroes.

The present study is the outgrowth of an investigation being conducted by the author. Anthropometric and somatological data obtained by T. Wingate Todd from Negro cadavers at Western Reserve University in the early 1920's and measurements obtained by Dr. G. K. Neumann at a later date on the same Negro crania are used in this study. In addition the statistical data for these cranial measurements as compiled by Dr. H. W. Neumann (3) is used. The statistical data for the cephalic measurements was calculated by the author. For purposes of this paper the cephalic statistics of 33 adjudged "full" Negroes is compared to the cranial statistics of a series of 81 adjudged "full" Negroes of which the series of 33 form a part. These specimens were adjudged "full" Negro on the basis of the cadaveral observations of Todd and classified visually on a varietal basis into Sudanid, Paleonegrid (Forest Negro) and Ethiopid groups. These observations were to be later substantiated by the work of Dr. H. W. Neumann. (3) The vast majority of the two series presented here belong to the Sudanid variety.

The purpose of this study is to present some data that may form a foundation for a more accurate estimation of either cephalic or cranial measurements when one of the two is not available. In surveying the standard Rudolf Martin (2) anthropometric blanks used for the cephalic measurements and the revised Harvard form for cranial observations and indices used as a basis for the cranial data, only 11 direct measurements and nine indices were found to correspond. Correspondence meaning that the measuring points are located essentially on top of each other in both the living and skeletal conditions. The comparison data indicates that even though these measurements were not compared specimen for specimen the amount of skewedness resulting from the larger cranial series is nil. Certain criteria which are questionable from the scientific point of view were overlooked only in this case because of the relative unavailability of published data of this type. Two of the most obvious inferences made here are that the cadaveral measurements coincide accurately with measurements obtained on the living and that there

is a lack of direct individual for individual comparison. The latter is to form a more complete and detailed study in the future. In addition a certain amount of latitude was allowed in the positioning of corresponding measuring points due to a lack of published evidence to the contrary.

The stated age of 27 of the 33 individuals of the cephalic series averages 28.5 years and ranges from 19 to 41 years. From this evidence we may assume that the sample represents a group of fully grown and developed individuals. It should be mentioned, however, that these individuals were by and large a socially unsettled type of migratory worker of low means, not typical necessarily of the more permanent Cleveland Negro population. They have been shown by anthropometric and photographic data to be rather ectomorphic somatologically, but the influence

TABLE 1

Corresponding Cranial and Cephalic Measurements With Difference in Millimeters and the Resulting Percent this Difference Represents of each Series Measurement

Cor. Measurements	Cranial Series Mean (81)	S.D.	Cephalic Series Mean (33)	S.D.	Correlation Factors Diff. in mm.	Percent of Difference
Length L	186.45	5.49	192.21	6.24	5.76	Ce. 2.99 Cr. 3.09
Breadth B	138.22	5.09	149.39	5.97	11.17	Ce. 7.48 Cr. 8.08
Min. Frontal MF	98.13	4.73	105.90	6.01	7.77	Ce. 7.33 Cr. 7.91
Porion-Apex Ht. PAH	112.73	3.89	123.30*	5.38	10.57	Ce. 8.57 Cr. 9.37
Total Facial Ht. TFH	124.45	5.82	129.33	6.45	4.88	Ce. 3.77 Cr. 3.92
Upper Facial Ht. UFH	74.22	4.06	73.45	6.25	Directly Comparable	
Total Facial Br. TFB	133.33	5.10	139.63	5.53	6.30	Ce. 4.51 Cr. 4.72
Dacryal Chord DC	23.07	2.05	34.98**	2.64	11.91	Ce. 34.05 Cr. 51.62
Nasal Br. BR	27.13	2.17	42.33	2.92	15.20	Ce. 35.93 Cr. 56.03
Nasal Ht. NH	52.57	3.07	54.36	4.03	1.79	Ce. 3.27 Cr. 3.40
Biangular Br. BA	99.38	6.03	112.36***	11.57	12.98	Ce. 11.55 Cr. 13.06

* Porion-apex height is used here as being equivalent to porion-tragus.

** Interorbital distance is used here as the nearest comparable measurement in living.

*** Bigonial breadth is used here as the nearest and only comparable measurement in the living.

this fact has on the comparative data presented here should be minimal since we are only dealing with the head and skull.

The eleven corresponding measurements selected are listed in Table No. 1. The mean dimensions for each measurement in both series are given in millimeters. The accompaning standard deviations are also given to demonstrate the dispersion of the two series. The standard letter symbols for each measurement are given to aid the reader in determining the derivation of the indices listed in Table No. 2. The precise location of each of the measuring points can be obtained by referring to the text of Comas' manual (1). For purposes of correlation the differences of the means in the two series were calculated. In order to further demonstrate the degree of correlation the percentage of the original mean as represented by the difference was calculated for each series mean measurement.

A survey of these results will show that the greatest percent difference found was 56.03%. This tremendous variation was obtained for the nasal breadth measurements and can be explained by the flaring ala nasi typical of the Negro. In all cases the variation in percentage differences can be explained by obvious anatomical features found in the living but absent in the skeletal condition. Another feature such as the nasal wings mentioned above might be the masseter muscle which covers the lateral surface of the ramus of the mandible and is largely responsible for the 12.98 mm. difference in the biangular (bigonial) measurements. Similar allowances for tissue depth could be made for all measurements listed. It should be noted, however, that it is not these obvious changes which occur in the living to skeletal transition but, rather, the degree of change that is important. The derivation of a mean nasal breadth of 27.13 mm. for a Negro cranial series is not unusual. However, being able to state with some accuracy that this measurement represents only 56.03% of the breadth of some Negro's nose is unique. This type of maneuver could be performed for each corresponding measuring point in order to suggest a correlation factor for tissue depth. Of the eleven corresponding measurements only the "upper facial height" is seen to be directly comparable. It can be said to be directly comparable in that being a single plane vertical measurement there is no correction necessary for tissue depth.

In Table No. 2 a list of indices obtained using only corresponding measuring points is given as well as their means and standard deviations. No correlation factors or percentage differences are given because in actual practice the corrections would be made on the direct measurement involved. The larger variation in indices occurs where metrical comparisons are most disturbed by tissue depth and form. In the directly comparable measurements and indices the variation is assumed to be due to the difference in the two series.

Considering the data presented here one could not propose a standard correlation factor for American Negro cranial and cephalic measurements. Perhaps the data does lay the groundwork for a later more complete and detailed study which might result in producing such a factor. As data is accumulated for other racial groups a series of factors could

TABLE 2

Corresponding Cranial and Cephalic Indices

Index	Cranial Series Mean in mm.	S.D.	Cephalic Series Mean in mm.	S.D.	Comment
Cranial B/L	74.06	3.05	77.75	3.08	Correction for greater neck muscle thickness
Transv. Fronto-Parietal MF/B	71.03	3.21	70.96	4.28	Directly comparable
Total Facial TFH/TFB	93.44	5.02	92.68	4.45	Directly comparable
Upper-Facial UFH/TFB	55.72	3.27	56.60	4.13	Directly comparable
Zygo-Frontal MF/TFB	73.65	3.51	75.71	5.77	Directly comparable
Cranio-facial TFB/B	96.52	3.51	93.96	5.75	Directly comparable
Nasal NB/NH	51.72	4.45	78.18	3.48	Correction for wings and height
Fronto-Mandibular BA/MF	101.48	7.47	105.66	8.76	Correction for masseter muscle
Zygo-Mandibular BA/TFB	74.56	4.09	80.00	8.52	Correction for masseter muscle

be made available. The value of such a correlation factor for the anthropologist is obvious, however, its possible applications in Anatomy, Art, Criminology and Medicine would extend the value.

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Cognatic Kinship Organization: Some Theoretical Considerations

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Within the past fifteen years, anthropologists have been concerned with the problem of nonunilinear descent. For many years, anthropologists have recognized the fact that all societies of the world do not have unilineal kinship systems, but there were no quantitative studies to determine the incidence of nonunilineal descent. Murdock (7) in his definitive work on social organization used a sample of 250 societies and noted that only 75 societies, or 30 percent of the sample, follow a nonunilinear rule of descent. The problem that arises is that of classifying the kinship organization of approximately one-third of the world's societies into definite structural units so that a comparative analysis of their attributes can be made.

Murdock's first attempt at classifying nonunilinear kinship systems led him to arrive at the concept of bilateral descent, which is defined as the absence of any unilinear emphasis (7). The kindred, he noted, is the commonest type of bilateral kin group. Murdock felt that the kindred is an attribute of all bilateral societies.

The presence of the kindred in a number of societies is noted by the fact that Ego knows and acts accordingly with certain relatives on both sides of his family. In societies where unilineal kin groups are absent, the kindred becomes an intermediate group between the nuclear family and the community. Given the definition that the kindred is a group of people related nonunilineally to a particular individual or sibling group, certain conceptual problems arise. The kindred, by definition, cannot be the same for any two individuals who are not siblings, and because of its personal nature, the personal kindreds of different persons overlap and intersect, rather than coincide. Kindreds are ego-oriented and their relationships are traced laterally rather than lineally, and their point of termination is collateral, usually with second cousins.

It is clear to see that kindreds are not permanent groups, their composition is always shifting; for this reason kindreds cannot form discrete and separate segments of an entire society. Although the kindred may define the jural rights of an individual, it can never act as a corporate group and hold property (land, material goods, religious secrets, etc.). As a matter of fact, the kindred is a kin group only from the point of view of one individual or sibling group.

Because the kindred cannot be defined in linear terms, students of social organization agree that it is not a full-fledged descent group. Mitchell (6) contends that the kindred is not only a characteristic of nonunilineal societies, but is a characteristic of all societies. Anthropologists have long recognized the fact that even in societies where unilinear kin groups are present, Ego is bilaterally filiated with both maternal and paternal relatives as far as kinship rights and duties are concerned. With this in mind, the concept of the kindred must be approached with some reservations: 1) we should recognize that the

kindred is an ego-oriented kinship structure and its membership consists of people who stand in a definite relationship to Ego; 2) that the concept of the kindred is valid in all societies; 3) that anthropological observations of the social participation of Ego with his kin is more important than native linguistic categories in the derivation of social structures; 4) that the term kindred is generic and refers to a variety of structural types; and 5) that the kindred, because it is ego-oriented, differs from the corporate kin group and that both groups have different system-references and cannot be abstracted from the same order of social relations. The kindred is not a valid descent group, because as we have seen, it is not structured along linear principles; its point of departure is ego and those who stand in a bilateral relationship to him.

Further investigations into the nature of nonunilinear descent groups have shed some light on different types of intermediate cognatic social structures. Goodenough (4:72) proposes a generic term for all societies where descent groups are composed of members who trace their relationships lineally through either or both sexes to a common known or unknown ancestor. Under the heading of "non-unilinear descent group," Goodenough classifies a variety of cognatic kinship structures. Davenport (1) has introduced the term "sept," and suggests that it be employed for kin groups where descent is reckoned ambilineally. The conceptual scheme of rules of descent originally proposed by Murdock (7) can no longer be used; his four rules of descent: patrilineal, matrilineal, bilateral, and double descent, must be revised. A new conceptual scheme would retain four rules of descent, but would replace bilateral with cognatic, and under this latter heading would be included all types of nonunilinear descent. An individual, in a society where unilinear rules of descent are absent, can reckon his kin by three cognatic principles: bilaterally, through all of his relatives, regardless of sex, on both the maternal and paternal sides; quasi-unilineally, very similar to unilinear principles but deviating sufficiently enough to warrant separate consideration; and ambilineally, through either parent but shifting from one side to the other in successive generations.

With cognatic kinship organization as the generic term for nonunilinear descent systems, it becomes possible to analyze a number of different types of intermediate kinship structures. Murdock (9) proposes that cognatic kin groups be classified into three different "kinship types," with linguistic and social criteria being the basis for this classification. The three types of cognatic kinship structures are: Bilateral/Eskimo; Quasi-unilineal/Carib; and Ambilineal/Polynesian.

In societies with Bilateral/Eskimo type kinship organization small domestic units are found to be prominent, and there is an absence of larger extended family units. Marriage is usually monogamous with occasional polygamy. Residence is either ambilocal or neolocal and unilinear descent groups are absent. Incest tabus do not extend to first cousins and cousin terminology is of the Eskimo type with lineal or bifurcate collateral avuncular terms.

Quasi-unilineal/Carib societies represent a transitory stage between cognatic and unilinear structures. Small domestic units give way to larger extended families. The rule of residence is usually unilocal and

incest tabus are not extended to first cousins. Cousin terminology is of the Iroquois type, distinguishing cross-cousins from parallel-cousins, and avuncular terms are bifurcate merging.

In Ambilineal/Polynesian type societies extended families are prominent, and the ramage is nearly always present. The rule of residence is ambilocal. Incest tabus are extended so that any type of cousin marriage is forbidden and, as would be expected, Hawaiian cousin terminology and generational avuncular terminology prevails.

All of the above classifications are for kinship systems and in two of the systems descent groups are present. In the Quasi-unilineal/Carib kinship system lineages are sometimes found as a result of the unilocal rule of residence coupled with the occurrence of large extended families. Ambilineal/Polynesian kinship systems are characterized by the presence of ambilineal ramages. A ramage is the functional equivalent of a lineage, it is a kin group in which membership depends on genetic relationships, not affinal ties. Just as lineages are susceptible to segmentation, so are ramages; just as the core of a unilocal extended family is called a minimal lineage, so can the core of an ambilocal extended family be called a minimal ramage. Murdock (9) suggests that the term "sept" be applied to a maximal ramage just as the term "sib" is applied to a maximal lineage. The major differences between a lineage and a ramage are two: first, membership in a lineage is exclusive, an individual can belong to only one group at a time, but membership in a ramage is nonexclusive (1); the second difference is that affiliation with a lineage is definitive, determined by a strict rule of descent, while membership in a ramage is more a matter of choice (3).

Goodenough (5) notes that ego-oriented and ancestor-oriented kin groups differ from each other in the fact that the former are laterally organized while the latter are lineally organized. In keeping with this distinction, Goodenough writes that "ancestor based or lineally organized groups are the only ones which can be properly called descent groups (5:1343)." The author of this paper has kept this distinction throughout and as it is a valid distinction, it channels the efforts of social scientists in the direction of laterally organized structures.

"Recognition of local groups organized as laterally rather than lineally oriented kin groups gives new substance to what Murdock (1949) called the 'deme' (5:1346)." This statement lends overwhelming support for the retention of the concept of the deme. The deme, like its unilinear counterpart, the clan, is both a genetic kin group and a residential unit, thus eliminating the need for any compromise. Membership in the deme is restricted to those individuals who are related to each other both laterally and lineally by either genetic relationships or marriage, and who reside together. For the most part, the deme is an endogamous local group with bilateral descent and as Murdock notes, it should be regard as a kin group rather than as a community (7:63).

Although the deme is defined as an endogamous local group, Murdock (7) was aware of the fact that exogamy might extend from the kindred to the entire community. This forces members of the deme to seek their spouses from outside of the community and in doing so, a unilocal rule of residence is usually followed, and the composition of the

group changes. If the rule of residence is matrilocal, the endogamous deme becomes an exogamous matrideme.

The deme, as has been noted above, is not only a kin group, but is also a community group. Driver (2:305) defines the deme as a "community (village or band) which is not further segmented by unilineal descent . . . ." Murdock (8:669) redefines the deme as "communities which reveal a marked tendency toward local endogamy without being composed of local exogamous units." The deme is the only kin group which does not divide the local community into members and non-members; its membership is non-exclusive.

In conclusion, the author wishes to point out that cognatic kinship systems are now being examined more thoroughly by students of social organization and it is hoped that this research will produce significant break-throughs into the types of intermediate structures. As demonstrated by this paper, only two types of cognatic kin groups on the intermediate level exist: the kindred, which is not a descent group, and the ramage, which is. On the level of the residential kin group, only the deme has been explained.

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BACTERIOLOGY

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ABSTRACTS

The Application of Immunology in Testing Anti-Allergic Agents for Clinical Use. Harry L. Murray, Paul S. Prickett, Howard R. Williams, Jr. and Paul M. Lish, with the technical assistance of Russel L. Stratman, Mead Johnson Research Center, Evansville.—Four basic immunological models, of which one is *in vitro* and three are *in vivo*, are applied to several drugs, such as aspirin, phenylbutazone, and aminopyrine to evaluate their anti-allergic action. In each model the guinea pig is the test animal. A battery of ancillary tests are also employed to differentiate true anti-anaphylaxis from some other undesired action. Ancillary tests are necessary only for those drugs showing apparent anti-anaphylaxis in the basic tests. Details of the types of action of the drugs mentioned will be described and compared with previously published information. We will attempt to define the usefulness of this group of tests for consideration of utility in inflammatory diseases with an allergy component.

Possible Influence of Salivary Antibody on Experimental Dental Caries in the Gnotobiotic Rat. Morris Wagner and Frank J. Orland, University of Notre Dame and University of Chicago.—Definitive studies in caries etiology have not been possible because of the ubiquitous and varied microorganisms present in the oral cavity of animals and man. Gnotobiotic technics have made it possible to elucidate upon specific bacteria capable of producing carious lesions in experimental animals. Germfree rats brought into gnotobiotic association with pure strains of certain streptococci developed typical carious lesions. Similar findings were reported at the National Institute of Dental Research.

Recent work has shown that gnotobiotic rats harboring a single homofermentative strain of lactobacillus could also develop caries. Germfree rats inoculated orally at weaning developed only an average score of 2.0 in gross caries intensity. Their progeny (2nd generation) showed an average score of 8.6 and the 3rd generation had an average score of 14.5. Coincident with these findings was the observation that while the first generation had serum agglutinins against the homologous organism, 2nd and 3rd generation animals did not. Furthermore, salivary antibody titers in the first generation animals were highest in the animals showing the lowest caries scores. It appears that presence of salivary antibody may have affected cariogenesis.

Infection of Cortisone-Treated, Germfree Mice with Mouse Hepatitis Virus. Philip P. Vella and Theodore J. Starr, University of Notre Dame.—The Gledhill strain of mouse hepatitis virus (MHV-1), free from

the enhancing agent *Eperythrozoon coccoides*, produces a fatal infection in newborn Swiss mice and is usually innocuous in weanlings and adults. The disease in newborns appears initially as focal lesions in the liver and gradually becomes diffuse. The infection in weanling and adult mice is enhanced in the presence of cortisone.

Swiss-Webster germfree mice and their genetically related conventional counterparts were inoculated with MHV-1 and cortisone. The inoculum usually administered to adult mice (0.1 ml, intraperitoneally) titered $10^{-3.0}$ newborn ID_{50}s. Cortisone acetate administered (IP) in single doses varied from 1.25-5.0 mg. Mice in the germfree, cortisone-virus group showed significantly fewer deaths. No deaths were observed in the cortisone and virus control groups. Surviving mice were sacrificed at 1, 2 and 3 weeks and autopsied for macroscopic liver damage. If mice survived the virus challenge in the presence of cortisone for 7 to 9 days recovery usually was inevitable.

Chemical Induction of Germfree Tumors. MORRIS POLLARD, University of Notre Dame.—Tumors have been induced in germfree mice and rats by chemical carcinogenic agents. Subcutaneous inoculation of sterile methylcholanthrene (MC) into newborn mice of Swiss-Webster strain induced lung tumors; in older mice transplantable sarcomas appeared in the inoculated area. Inoculation of MC into rats resulted in sarcomas at the inoculation area. One feeding of sterile 7, 12 dimethylbenzanthracene (20 mg) in sesame oil to 50 day old Sprague-Dawley rats resulted in cancer of the breast in all of them. Examinations of animals and tumors for viral flora by conventional tissue culture and electron microscopy were negative. The tumors resembled in gross and histological character the tumors observed in conventional animals. The results suggest that while viruses are involved in specific oncogenic processes, they were not of concern in those described above. The effects of oncogenic viruses and physical factors on germfree animals are being studied.

Colchicine-induced, Micronucleated, Tissue-cultured Cells. THEODORE J. STARR, University of Notre Dame.—The effect of colchicine on mitosis of a tissue-cultured cell line was followed by fluorescence microscopy of acridine orange-stained preparations. The formation of micronucleated cells is described at the chromosomal level. DNA synthesis was followed by autoradiography with tritiated thymidine. Despite the gross structural changes involved, micronucleated cells maintained its functional capacity to incorporate thymidine and to support the predictable maturation process of the agent of psittacosis.

Inhibition of Macromolecular Syntheses in *Escherichia coli* by Phenethyl Alcohol. RONALD W. TREICK and W. A. KONETZKA, Indiana University.—When *Escherichia coli* is inhibited by phenethyl alcohol an unbalanced synthesis of deoxyribonucleic acid (DNA), ribonucleic acid (RNA) and protein is observed. This report deals with the relationship between the concentration of phenethyl alcohol and the physiological state of the cells on the inhibition of macromolecular synthesis in *E. coli*. Concentrations of inhibitor ranging from 0.25% to 0.35% (v/v) do not allow cell division during a period of at least 4 hours, but the

cells remain viable. Increasing concentrations of phenethyl alcohol added to exponentially growing cells causes a progressively greater inhibition of the rate of RNA and protein synthesis. DNA synthesis is completely inhibited after an increase which is never greater than double the amount of DNA initially present. Moreover, the physiological state of the cells at the time of addition of the inhibitor markedly influences the patterns of syntheses of DNA, RNA, and proteins. Upon removal of phenethyl alcohol the syntheses of the three polymers is resumed and is followed by cell division. The results indicate that phenethyl alcohol can be employed to inhibit specifically DNA synthesis during the synthesis of RNA and proteins.

Multiple Nitrate Reductases in *Bacillus subtilis*, R. J. DOWNEY and H. POLLARD, University of Notre Dame.—A particulate nitrate reducing system has been studied in *Bacillus subtilis* grown in a peptone-nitrate medium. This enzyme system catalyzed the reduction of nitrate to nitrite by NADH under aerobic and anaerobic conditions. Oxidation of NAD-linked substrates by the soluble enzyme proceeded at a rate which greatly exceeded that of the particulate system. The latter was observed to require a vitamin K-like naphthoquinone for activity whereas only menadione (K_3) was capable of restoring the former. Nitrate reduction via the particulate system was greatly stimulated by catalytic amounts of FAD.

Spectral analyses of a chromatographically purified soluble system disclosed no detectable hemeproteins. Carbon monoxide, antimycin A and gramicidin inhibited only the particulate system while azide, cyanide and dicumarol strongly inhibited both. Although nitrite in high concentrations only partially inhibited the soluble reductase, it completely inhibited the bound enzyme. The study suggested that nitrate reduction in *Bacillus subtilis* is accomplished by two related but essentially dissimilar mechanisms. The soluble complex transports electrons through a quinone reductase while the particulate complex appears to utilize the conventional flavin-heme sequence.

Influence of *Salmonella typhimurium* on Ileum and Spleen Morphology of Germfree Rats[1]

P. Leonard Knight, Jr.[2] and Bernard S. Wostmann,
University of Notre Dame

Introduction

Comparative studies in germfree and conventional chickens and rats by Gordon and Bruckner-Kardoss (4) and Abrams et al. (1) in mice, have indicated that the presence of a normal flora has an effect on the morphological characteristics of the intestine. Gordon and Bruckner-Kardoss (4) found that the germfree chicken generally had less lymphoid tissue in the ileum than did the conventional animal of the same age. Unpublished reports by Gordon also confirm this in male rats. Abrams et al. (1) showed that cellular renewal of ileal epithelium occurs at a much slower rate in germfree mice than in their conventional counterparts.

The effects of microbial flora on lymphatic tissue such as the spleen have recently been investigated by Bauer et al. (2) in mice; Thorbecke et al. (9) and Gordon (3) in chickens; Miyakawa et al. (6) and Sprinz et al. (8) in guinea pigs and Gustafsson (5) in rats.

The studies presented here extend the above observations to the rat which has been monoassociated with *Salmonella typhimurium* and more specifically to the effects this species has on the cellular elements of the intestine (ileum) and the morphology of the spleen.

Materials and Methods

Approximately 120 day old germfree female rats were orally seeded (as a monoassociate) with *Salmonella typhimurium* (strain 750). One group of animals was sacrificed after one day of association, while the other groups were sacrificed after 2, 3, 5, 8, 11 and 18 days. 120 day old germfree and conventional rats were also sacrificed as control animals. Animals were sacrificed by bleeding using nembutal anesthesia. The ileum and spleen were removed, embedded in celloidin and paraffin after the method of Apathy (7) and sectioned (5μ thick). Sections of the ileum were stained with hematoxylin, Azure II, and eosin, while the spleen sections were stained with methyl green pyronine.

Cellular elements were counted using a Net Reticule (American Optical Co.). The 100 mm^2 area of the reticule was divided into 0.5 mm squares. Using 970 x magnification only those nuclei of cells which "fell" under intersected lines of the 0.5 mm squares were counted. This procedure left very few cells unaccounted for. The cells of the villus and those of the areas of the submucosa and muscularis beneath the villus were counted. Three villi, selected at random, were counted for

1. This research was supported by grants from the Office of Naval Research and the National Institutes of Health.

2. St. Mary's College.

every animal and three or more animals were used for each determination. The arithmetic mean of these nine values are given in the table. These means are expressed as parts per thousand of the intestinal wall occupied by the listed tissue element.

Results and Discussion

Spleen Morphology.

Twenty-five mm^2 spleen sections of all animals were observed. The presence of bacteria (a complete flora or one species) did not seem to influence the number of follicles—the mean in all animals being approximately 18. Although follicles of both germfree and conventional animals varied greatly in size, the average dimensions were the same in both groups. In the monoassociated rats up to the fifth day of exposure the follicles were extremely large, thus leaving very little red pulp. After the fifth day they resembled those of the germfree and conventional animal. The presence of bacteria had little or no effect on the intermediate sinus. Germinal centers were observed in conventional, germfree as well as monoassociated animals.

The white pulp of germfree, conventional and monoassociated animals showed very little pyroninophilia in both inner and outer zones. The red pulp of monoassociates up to 5 days exposure resembled that of the germfree i.e. few pyroninophilic cells. After 5 days, however, extreme pyroninophilia was observed. Even after 18 days exposure to *S. typhimurium*, the red pulp still contained a large number of pyroninophilic cells.

Ileum Morphology.

A. Gross Changes

After the ileum of the germfree rat had been exposed to *S. typhimurium* for 2 days, there was a decrease in the number of villa. Epithelial cells were absent from the mucosal layer and thus the connective tissue was exposed to the action of the food, digestive enzymes and bacteria. Abrams et al. (1) found after treating the ileum of conventional mice with tritiated thymidine that the labeled epithelial cells reached the extrusion zone at the tip of the villus in approximately 2 days. It is conceivable therefore that after a germfree rat has been challenged by *S. typhimurium* for 2 days, that cellular proliferation in the crypts does not keep pace with epithelial loss from the extrusion tip; the result—a loss of epithelial cells lining the lumen and ultimately a partial or total destruction of the villus.

Five days after exposure the number of villi was "normal" but the epithelium of the villi was frequently separated from the underlying connective tissue. This separation may be a physical phenomenon wherein during the repair phase connective tissue proliferation does not keep pace with increased epithelial proliferation and migration, or it is possible that this represents a "physiologic inflammation." From the first to the fifth day of exposure there was a general increase in the number and length of the crypts of Lieberkuhn. After the eighth day the crypts and villi appeared "normal" both in length and number, resembling at this time those of the ileum of conventional rats.

B. Cellular Changes

TABLE I

Distribution (parts per thousand) of cells of the villi and of adjacent submucosa and muscularis layers of the ileum of 120 day old germfree, conventional and *Salmonella typhimurium* associated female rats. Each figure represents the mean from 9 or more randomly selected areas, from three or more different microscopic preparations (animals). S.D.M. values given.

			Days after Exposure to *Salmonella typhimurium*				
	Germfree	Conv.	1	3	5	8	11
Epithelium							
Villus epithelium	288 ± 16.8	199 ± 22	195 ± 26.1	103 ± 40.1	140 ± 16.6	147 ± 21.5	160 ± 24.8
Lieberkuhn epithelium	97 ± 14.3	124 ± 10.5	188 ± 20.4	245 ± 22.8	283 ± 20.5	218 ± 20.5	230 ± 8.1
Goblet	34 ± 7.5	25 ± 4.7	15 ± 6.8	2 ± 0.4	10 ± 5.2	6 ± 0.7	8 ± 1.0
Lymphocytes	2 ± 0.1	6 ± 1.1	2 ± 0.4	0+ ± 0.4	1 ± 0.4	1 0	1 0
Schollen leucocytes	1 ± 0.1	1 ± 0.2	0 0	0 0	0+ ± 0.9	0 0	1 0
Lamina propria and Submucosa							
Conn. elements	151 ± 21.6	137 ± 6.6	128 ± 31	206 ± 37.0	194 ± 15.8	248 ± 9.4	180 ± 7.4
Lymphocytes	13 ± 4.6	52 ± 6.9	5 ± 0.3	8 ± 0.4	11 ± 2.2	14 ± 4.1	9 ± 0.1
Ring	3 ± 1.0	4 ± 0.2	6 ± 5.5	9 ± 2.6	2 ± 0.4	1 ± 0.4	5 ± 2.5
Eosinophils	4 ± 1.3	10 ± 2.1	3 ± 0.2	2 ± 0.4	6 ± 2.2	2 ± 0.4	4 ± 1.0
Mast	0+ —	1 ± 0.2	1 ± 0.5	0+ ± 0.4	5 ± 1.3	0 0	0+ —
Plasma	1 ± 0.1	16 ± 7.3	4 ± 1.8	3 ± 0.6	1 ± 0.6	8 ± 2.7	6 ± 1.0
Muscle	5 ± 2.3	6 ± 1.8	26 ± 3.1	20 ± 4.8	15 ± 0.7	12 ± 2.3	14 ± 1.1
Muscle							
Circular	263 ± 18.6	251 ± 15.2	291 ± 16.8	251 ± 14.0	235 ± 20.0	230 ± 89.9	230 ± 6.0
Longitudinal	142 ± 10.9	159 ± 16.7	134 ± 9.2	152 ± 32.5	102 ± 3.8	113 ± 4.9	148 ± 7.2

The distribution of cells in the ileum of germfree, conventional and monoassociated rats is given in Table I. The germfree and conventional cell counts are generally of the same order of magnitude as Gordon (unpublished data) obtained with male rats on diet L-356. Gordon, however, did find many more lymphocytes and Schollencytes in the epithelial layer of the conventional rats than in the corresponding part of the germfree. Results in the table show that there are only 3 x as many lymphocytes in the epithelial layer of the conventional as in that of the germfree rat. The difference between Gordon's and these results may possibly be due to diet, sex or to both.

The number of villus epithelial cells of all monoassociates is less than either germfree or conventional; however, the Lieberkuhn cells increase, reach their peak the fifth day after exposure and then decline. Goblet cells are fewer in number in all monoassociates as compared to both germfree and conventional. Schollen leucocytes of germfree, conventional and monoassociates are of the same order of magnitude.

The connective tissue elements of the lamina propria and the submucosa increase up to the eighth day of exposure and then decline. The number of lymphocytes remains approximately the same as germfree and never equals the number found in the conventional rat.

Ring cells reach a peak on the third day; eosinophils on the fifth day and plasma cells on the eighth day after exposure. Monoassociates have many more muscle cells in the lamina propria and muscularis mucosa than either germfree or conventional rats.

There appears to be no appreciable difference in the muscularis layers of germfree, conventional and monoassociated animals. It is to be noted, however, that in all three groups the circular muscle layer is approximately twice as thick as the longitudinal.

These observations seem to indicate that most of the significant histological changes in the ileum and spleen (with limited data for this organ) occur between the second and the eighth day after exposure to *Salmonella typhimurium*. It appears that these changes (accompanied by or preceding phagocytic activity and antibody formation) have occurred to meet the challenge of the invading bacteria.

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Intestinal Microflora and Cholesterol Catabolism[1,2]

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Although the direct relationship between serum cholesterol and atherosclerosis remains obscure, recent data again indicate that most, if not all, of the cholesterol found in aortic lesions is derived from the circulating blood (1). In the etiology of coronary heart disease high cholesterol levels are considered a danger sign and the reduction of body cholesterol pools is regarded as being of major importance in both prophylaxis and treatment (2).

The loss of cholesterol from the body pools is mainly determined by its oxidative conversion to bile acids and by the loss of cholesterol and its bacterial conversion products in the feces. The main catabolic pathway, the conversion to bile acids, presumably is controlled by the size of the bile acid pools (3). The turnover of bile acid pools is strongly reduced in the absence of an intestinal microflora (4). Thus the metabolism of cholesterol is influenced in diverse ways by the various components of the intestinal flora, but the sum of these effects would presumably increase the turnover of cholesterol in the body pools because of an increased loss of cholesterol's major metabolite, the bile acids. This seems to be reflected in the higher liver cholesterol values found in germfree rats of all ages (5).

The purpose of the study presented here was the development of a system in which the above presumptions could be tested. As a first approach we studied the turnover of cholesterol -26-C^{14}, both in the presence and in the absence of a "normal" intestinal microflora. The results indicate an increase of 50% in cholesterol catabolism over "germfree" values in the presence of an intestinal microflora. A more complete report of this work will be published elsewhere.

Materials and Methods

Three to 5 months old male germfree and conventional rats of the Lobund strain (of Wistar origin) were used. The diet was L-356, a semisynthetic formula containing 20% casein, 60% rice flour, 7% corn oil, yeast, liver extract, vitamins and minerals (6). After injection of approximately 6-7 μC of cholesterol-26-C^{14}, solubilized with Tween 20, into the femoral vein, the experimental animal was housed in a plexiglas, gas-tight metabolism chamber (20 x 20 x 16.5 cm), provided with an inlet and outlet for air. Incoming air was dried and freed of CO_2. Outgoing air was conducted through three wash bottles containing 5 N NaOH to trap expired CO_2. In the germfree experiments this system was enclosed in a sterile plastic isolator and the air passing through the metabolism chamber was sterilized by passage through a

1. These studies were carried out by Mr. Norbert L. Wiech and Mrs. Elizabeth J. Küng.

2. These studies were aided by grants from the Nutrition Foundation, Inc., the Office of Naval Research and the National Institutes of Health.

fiberglas filter. In all experiments an airflow of 2.0-2.5 liter/min. was maintained. The experimental period was 72 hours, after which the animals were removed from the metabolic chamber and sacrificed for organ analysis. The expired trapped CO_2 was precipitated as $BaCO_3$ and plated on planchets for determination of radioactivity. Liver and carcass were homogenized and the separation into water soluble, lipid and unsaponifiable fractions was achieved following generally accepted methods. The beta sterol fraction was isolated after saponification via digitonin precipitation (7). Aliquots of these fractions were used for the determination of radioactivity.

The specific activity of total cholesterol in liver and carcass was obtained by dividing the counts in the digitonin precipitated samples by the amount of total cholesterol as determined by our modification of the Liebermann-Burchard method (5). Only in the case of plasma was the specific activity calculated by taking the total radioactivity of the sample divided by its cholesterol content.

Results and Discussion

After a 72 hour experimental period, on the average 92 ± 1% of the C^{14} label could be recovered in expired air, liver, carcass, cecal contents, and excreta. Calculated on the total recovered dose, the

TABLE I

C^{14} distribution after cholesterol-26-C^{14} administration to adult germfree and conventional male rats. Time: 72 hours.

Diet: L-356.	Germfree	Conventional	
Total	100	100	
Expired air	22	32	s
Carcass beta-sterol	55	46	s
other	3	4	
Liver beta-sterol	11	8	s
other	2	2	
Excreted in feces	3	5	s
Balance (urine, blood, cecal content etc.)	4	3	

distribution of the label is given in Table I. The data indicate a 50% increase in oxidative cholesterol conversion over germfree values, obviously caused by the presence of the intestinal microflora. A correspondingly lower retention of the originally administered cholesterol-26-C^{14} in indicated by the lower values found in the carcass and liver beta sterol fraction of the conventional rats. The significantly higher excretion of label with the feces in these animals presumably represents an increased loss of cholesterol as coprostanol or other bacterial conversion products in which the side chain remains intact.

In vitro studies by Suld et al., suggest the possibility of the loss of the last 3 carbon atoms of the side chain as a unit which then, for the

most part, would enter the tricarboxylic acid cycle and lead to extensive reincorporation of the tracer (8). Such an effect would seriously endanger the interpretation of experiments in which the liberation of $C^{14}O_2$ from cholesterol-26-C^{14} would be taken as a measure of the rate of oxidative catabolism of cholesterol. However, the data in Table

TABLE II

C^{14} distribution in liver after cholesterol-26-C^{14} administration to adult germfree and conventional male rats. Time: 72 hours. Diet: L-356. SDM values given.

Per cent dose in:	Germfree (7)	Conventional (10)	
total	11.0 ± 0.8	9.7 ± 0.4	
water sol.	0.4 ± 0.1	0.1 ± 0.1	
lipid	10.2 ± 0.4	8.6 ± 0.6	
unsapon.	10.0 ± 0.7	8.2 ± 0.5	
beta-sterol	9.8 ± 0.7	7.5 ± 0.3	s
Total liver cholesterol/ 100 gm body weight	13.0 ± 0.6	13.3 ± 0.6	
Spec. activity*	744	589	s

* % dose/mg/min./100 gm body weight x10^3.

II show that most of the radioactivity found in the liver can be accounted for as the originally injected labelled cholesterol (beta sterol fraction). Some C^{14} containing water soluble metabolites apparently occur and a slight reincorporation into other lipid fractions, like the fatty acids, may be indicated. However, as the data in Table III indicate,

TABLE III

C^{14} distribution after cholesterol-26-C^{14} administration to adult germfree and conventional male rats. Values in per cent dose. SDM values given. Time: 72 hours. Diet: L-356.

	Germfree (8)	Conventional (10)	
Expired air	19.3 ± 1.5	29.7 ± 1.7	s
Liver (beta-sterol fract.)	9.8 ± 0.7	7.5 ± 0.1	s
Carcass (beta-sterol fract.)	48.3 ± 2.1	42.5 ± 1.7	s
Total	77.4	79.7	

expired $C^{14}O_2$ plus the original cholesterol-26-C^{14} in liver and carcass account for about 78% of the originally injected dose (and for 87% of the recovered dose). This calculation leaves the partially unidentified form of the label, as present in feces, urine, blood and cecal contents still

unaccounted for. Thus, it would seem that in the intact rat the expired $C^{14}O_2$ is a good indicator of the cholesterol-26-C^{14} cholic acid conversion.

All data indicate an increase of oxidative conversion of cholesterol in the conventional animal and a correspondingly lower retention in its liver and carcass, while body cholesterol pools are approximately the same size in both experimental categories. This leads to the differences in specific activity of the cholesterol in liver and plasma as shown in Table IV. The data also demonstrate that the equilibration of the

TABLE IV

Specific activity of beta-sterols after cholesterol-26-C^{14} administration to adult germfree and conventional male rats. Values in % dose/mg./min./100 gm body weight x10^3. SDM values given. Time: 72 hours. Diet: L-356.

	Germfree (8)	Conventional (10)
Plasma*	889 ± 74	685 ± 64 s
Liver	744 ± 63	589 ± 37 s
Carcass	478 ± 31	422 ± 35

* Total activity.

carcass cholesterol fraction proceeds relatively slow, causing the specific activity in this pool to lag behind that of the liver.

The main mechanism involved in the increased cholesterol catabolism seems to be the bacterial clearage of the conjugated bile acids (4), and possibly the dehydroxylation in the 7-position (9), both effects that tend to make the bile acids less available for reabsorption. By fecal elimination of bile acids, a faster oxidative catabolism of cholesterol becomes possible, which brings body cholesterol pools to a lower level.

Thus intestinal microorganisms help to eliminate a potentially dangerous metabolite. A next step will be to determine, with the help of gnotobiotic techniques, which components of the intestinal microflora are instrumental in increasing cholesterol catabolism. And in the distant future we foresee the possibility that dietary and other means will regulate the composition of the microflora to a point where the presence of bacterial species with a potentially beneficial effect, like the one illustrated above, could be enhanced.

Summary

The degradation of cholesterol was studied in germfree and conventional rats with the help of cholesterol-26-C^{14}. The major part of the tracer liberated from the cholesterol molecule during the oxidative conversion could be recovered as $C^{14}O_2$ from the expired air. The results indicate a 50% greater degradation of cholesterol in the presence of a "normal" intestinal microflora.

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BOTANY

Chairman: J. H. MAYSILLES, Hanover College

P. A. ORPUT, Manchester College, was elected chairman for 1964

ABSTRACTS

A New Station for *Butomus umbellatus* L. in Indiana. S. W. WITMER, Goshen College.—This species, thus far unreported for Indiana, was discovered by the author in the hydraulic canal off the Elkhart River at the city of Goshen, Elkhart County, Indiana on July 4, 1952. The plants were in full bloom and growing in shallow water. Later the plants were also found along the bank at different points in the main body of the river. The past summer of 1963 the species was seen at many points for a distance of about 3 miles along both canal and river. It should be considered as a new addition to the flora of Indiana. Introduced in some unknown manner from the Eastern Hemisphere, this species was first observed in North America in the St. Lawrence River in Quebec about 1897. Later (1929) the plant was reported from the New York and Vermont shores of Lake Champlain. Within the next two decades the plant appeared on the Michigan, Ohio and Pennsylvania shores of Lake Erie. *Butomus umbellatus* may encroach upon some indigenous species but is desirable for teaching material and has special advantages for morphological and cytological studies.

Loss of Rubidium^{86} and Phosphorus^{32} from Forest Leaf Litter at Three Seral Levels, Parke County, Indiana. ROBERT PETTY, Wabash College.—Decay release and soil mobility of two radionuclides is reported for three seral levels of mesic vegetation, viz. an abandoned field, a mid-seral oak stand and a virgin beech-maple forest. The study concentrates on early mineral release as a function of physical versus biologic phenomena. Leaves of beech (*Fagus grandifolia*), maple (*Acer saccharum*) and tulip poplar (*Liriodendron tulipifera*) were utilized. Findings indicate that beech, which decays slowest of the three, loses rubidium most rapidly (as RbCl and considered here analogous to K), while tulip poplar, which decays fastest, is slowest in initial salt loss. Release of rubidium is related primarily to physical factors in the three vegetation types, while rates of phosphorus loss correlate to actual decay (dry weight loss). Methods of introducing radioactive materials into woody plants is also discussed.

A Histological Study of Host Parasite Relations of *Puccinia polysora* and *P. sorghi* on Different Genotypes of Maize[1]

W. C. von Meyer, Purdue University

Introduction

Histological studies of plants resistant to rusts and other pathogens have led to two principle classifications of disease resistance, functional and protoplasmic. In functional resistance the host hampers penetration (1, 5, 6). In protoplasmic, the potential pathogen may enter, grow slightly and die, or may cause the collapse of host cells around the hyphae supposedly limiting nutrient supply and preventing sporulation. The immediate collapse of host cells in response to penetration has been termed hypersensitivity (13). At present, degrees of sporulation, which are often termed degrees of infectivity, are the means by which reaction types of the rust pathogens are distinguished, but these indicate little of what happens inside the host.

The amount of sclerenchyma tissue may limit the spread of the hyphae and thus the size of pustules (3, 6, 10, 12), but some workers have concluded that resistance was protoplasmic rather than structural (13), or suggested that protoplasmic resistance reduced the vigor of the parasite so that morphological factors might prevent sporulation (16).

Storey (15) described the resistant reactions to *P. polysora* as follows: "Ol-a," a slightly shrunken yellow fleck; "1++," a brown lesion with a tiny central pustule; "X," varying pustule sizes. Responses to *P. sorghi* have been noted as "1-" for chlorotic flecks (7) while Flangas et al. (4) mentioned only necrotic flecks and termed them "O" types. It is thus apparent that no uniform system of naming reaction types for the corn rusts exists.

This paper reports the histological examination of resistant and susceptible reactions of maize leaves to the two corn rusts, *Puccinia polysora* Underw. and *Puccinia sorghi* Schw.

Materials and Methods

Maize seedlings were inoculated by spraying a water suspension of the urediospores onto the leaves and placing the plants in a moist chamber in the dark for 16 hours. The plants were then kept in the greenhouse at 80°F. until symptoms developed.

The genotypes employed were selections from specific plant introductions and an inbred line derived from the variety Cuzco. Cuzco seed was originally obtained through the courtesy of P. M. le Roux, in 1954. The responses of the selections are shown in table I:

1. Journal paper number 2194, AES.

TABLE I. Symptoms obtained on various hosts

hosts	*pathogens*	
	P. polysora	*P. sorghi*
P.I. 163558	minute pustule	necrotic fleck
P.I. 163597	chlorotic fleck	large pustule
P.I. 186208	chlorotic fleck	large pustule
P.I. 172332	necrotic fleck	large pustule
Cuzco	large pustule	chlorotic fleck

The above reactions represent the types observed except a water-soaked reaction. This appeared as a brownish orange, translucent fleck which was induced by high temperature and humidity acting on chlorotic flecks. "Watersoaking" often extended beyond the infected areas, notably on P.I. 186208 and P.I. 198902.

Leaf tissues were sampled at various intervals after inoculation. Frozen sections of 30 μ were prepared in water without fixation while other tissues were fixed in FAA or 1:1 acetic acid-ethanol. Before imbedding, tissues were dehydrated in tertiary butyl alcohol solutions and imbedded in "Histowax." Sections were stained with safranin in 70% ethanol followed by fast green in 95% ethanol. Geimsa's stain was used in water, and trypan blue in 95% ethanol containing 1% acetic acid by volume. The latter was used with whole mounts to show the infection structures, while the hyphae in whole mounts were demonstrated by boiling fresh tissues in 10% KOH until clear and soft, washing in hot 0.5% picric acid, staining in picro-aniline blue at 100°C. for 5-10 minutes, and washing out excess stain in 70% ethanol containing a trace of picric acid.

Results

Reactions to *Puccinia polysora* varied from necrotic flecks to large pustules and differed from those produced by *P. sorghi* on the same plants. Penetrations were similar on resistant and susceptible hosts, and were accompanied by large, thin-walled appressoria and vesicles (plate I) which for *P. sorghi* were unlike those formed on water agar (11). The chlorotic fleck type developed 3-5 days after inoculation and sections and whole mounts showed that the hyphae grew slowly between the cells without forming haustoria (plate II, fig. 2). Only two haustoria were found in chlorotic fleck inducing hosts; these were in an epidermal cell in a watersoaked area. A mass of compacted chlorenchyma cells surrounded by mycelium was found at 7-10 days. During this period the tissue collapsed slightly but no hypertrophy or hyperplasia was observed. At 7 days, frozen sections showed that the plastids were not destroyed but lacked chlorophyll. After 9-12 days the chloroplasts dissolved and the mesophyll collapsed, so that eventually only the vascular bundles and adjacent border parenchyma cells remained visible. In contrast, the necrotic fleck was accompanied by the complete and immediate collapse of the host cells at the penetration cite (plate III, fig. 4). At 80°F. the

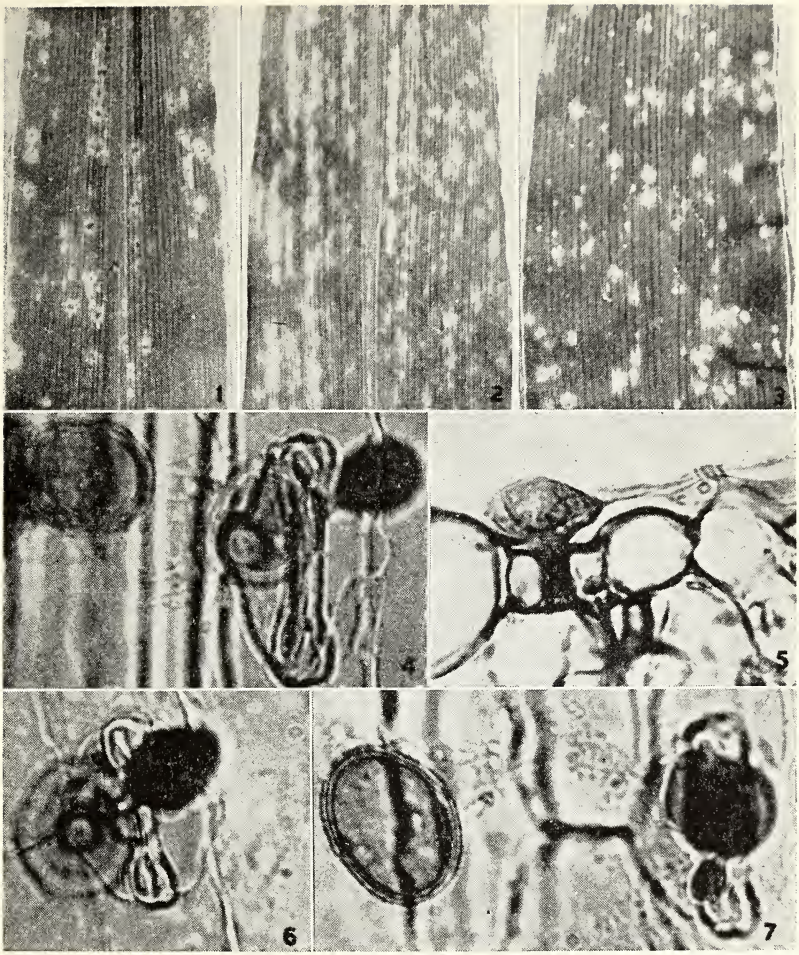

PLATE I

1. Minute pustules in necrotic flecks.
2. Diffuse chlorotic flecks, *P. sorghi* on Cuzco 8 days after inoculation.
3. Necrotic flecks, *P. polysora* on 172332 at 10 days.
4. Left to right: spore, appressorium, vesicle of *P. polysora* on susceptible leaf.
5. Cross esction of chlorotic fleck produced by *P. sorghi* on Cuzco, 6 days.
6. Appressorium and vesicle of *P. polysora* on P.I. 186208.
7. Spore, appressorium, and tiny vesicle of *P. sorghi* on Cuzco.

collapsed areas reached a maximum size 12 days after inoculation and appeared as white, parchment-like spots (pl. I, fig. 3) sharply delimited by healthy tissue. Border parenchyma cells remained turgid. At 12 days, only a thin line of broken and compacted cells remained so that both upper and lower epidermis were brought together. Cell penetration was not shown. Hyphae at the edges of the flecks suggested that growth of the parasite was essential for collapse. These hyphae appeared com-

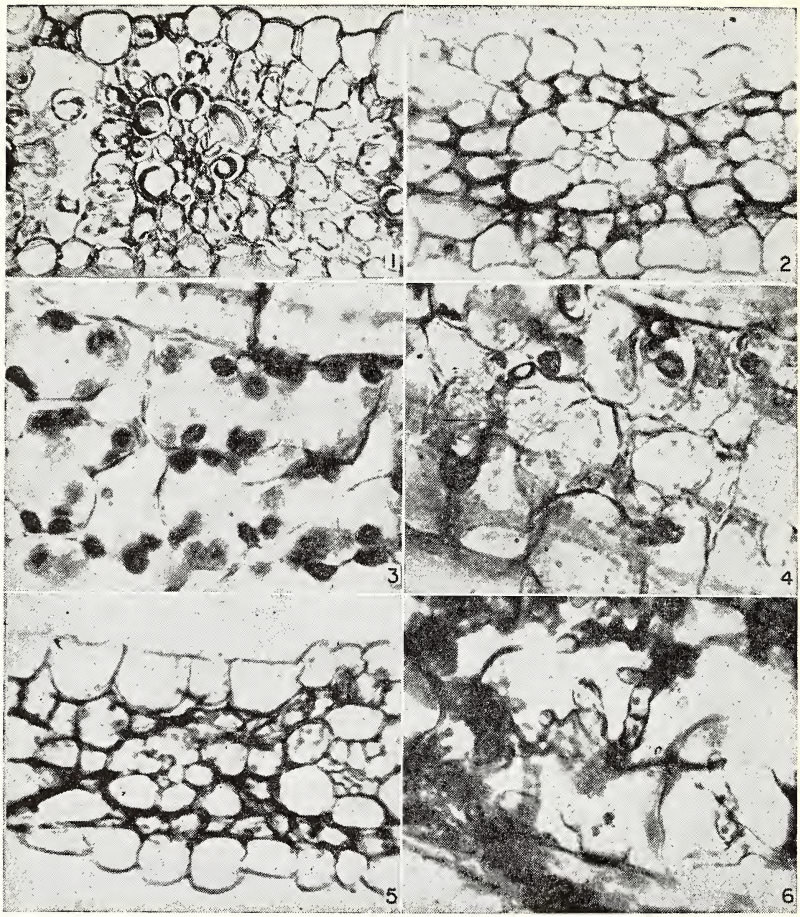

PLATE II

1. Healthy leaf on P.I. 186208, cross section.
2. Cross section showing intercellular hyphae of *P. polysora* at 8 days in a chlorotic fleck.
3. Mesophyll cells of healthy P.I. 186208.
4. Mesophyll of P.I. 186208 10 days after inoculation with *P. polysora* showing watery intercellular hyphae.
5. Cross section of chlorotic fleck produced by *P. sorghi* on Cuzco, 6 days.
6. Mass of hyphae of *P. sorghi* found in mesophyll of chlorotic fleck, 8 days.

pressed, forming ribbon-like bands above and below the border parenchyma cells. A third host response was a necrotic fleck with a minute central pustule. The pustules formed at 10 days at 80°F. Sections showed few haustoria were formed and sporulation was enhanced by placing the plants in a moist chamber 7-9 days after inoculation. Sporulation on susceptible plants required 8-10 days, and whole mounts showed the projection of haustoria (pl. III, fig. 2, 8) into cells from intercellular hyphae which were 2-4 μ in diameter. Often, the hyphae completely

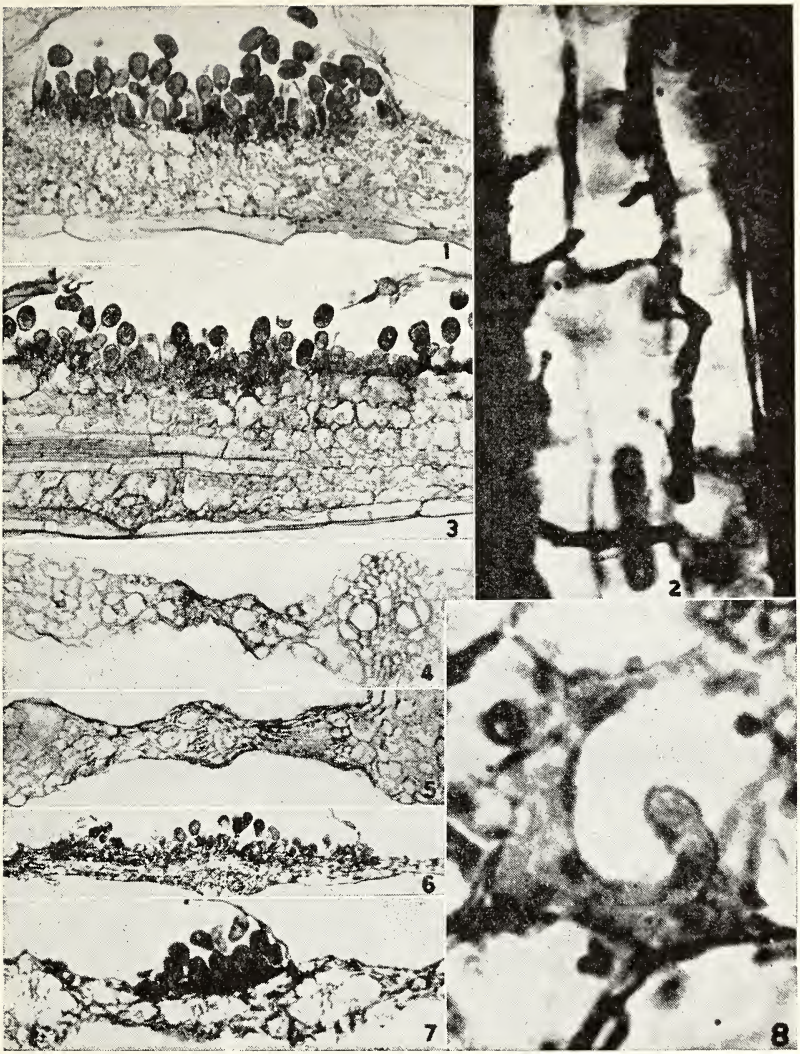

PLATE III

1. Susceptible reaction, *P. polysora.*
2. Hyphae and haustoria of *P. polysora* in susceptible leaf.
3. Susceptible reaction, *P. sorghi,* showing host cell distortion below pustule.
4. Cross section of necrotic fleck, 4 days, *P. polysora.*
5. Cross section of necrotic fleck, 5 days, *P. sorghi.*
6. Minute pustule reaction, *P. sorghi,* 7 days, note necrosis.
7. Minute pustule reaction, *P. polysora,* 9 days.
8. Haustorium of *P. sorghi* in susceptible leaf.

occupied the intercellular spaces at the junctures of 3 or 4 cells, forming large diamond and star-shaped structures. At places where pustules formed, the mass of hyphae might exceed the host tissue in volume and

considerable strain was evident by the distorted host cells (pl. III, fig. 1, 3). Hyphal growth appeared requisite for pustule formation as evidenced by the area of spread of the hyphae around pustules.

Host responses to *P. sorghi* were like those of *P. polysora* but developed 2-3 days faster than *P. polysora* at the same temperature. The chlorotic flecks were produced 2-4 days after inoculation and sections showed only intercellular hyphae. After 6-8 days there was a slight collapse of host cells. The hyphae grew abundantly between the cells but were compressed as if unable to move the host cells apart. Occasionally, at the centers of flecks a mass of hyphae was found (pl. II, fig. 6) but no true pustule initials. Similarly the hyphae were abundant in the necrotic fleck reactions but collapse was severe (pl. III, fig. 5) and sporulation was prevented. But where minute pustules were formed this collapse did not prevent spore formation and a few haustoria formed. Haustoria of *P. sorghi* always appeared as single hyphae and as many as three were found in one cell. No branching was observed. Numerous haustoria formed immediately below the pustules and were like those of *P. polysora.* The pustules of *P. polysora,* as with *P. sorghi* were accompanied by great host cell distortion to accommodate the pustule initials. Dicaryons were clearly seen in the hymenial-like layer below the spores.

Discussion

The results allow the comparison of similar resistant reactions on a single host species produced by different rust species. The immediate and complete collapse of host cells was associated with macroscopic white flecks but, where growth occurred between the cells without immediate collapse, a chlorotic fleck formed. There was no evidence of haustoria of either rust in the necrotic and chlorotic flecks. Since the collapse of host cells might have obscured any haustoria present, the statement "no haustoria" has some reservation. In all chlorotic and necrotic flecks the hyphal growth was restricted to the intercellular spaces more than in the susceptible leaves. This was particularly obvious in the chlorotic flecks and may have been the result of high cell wall strength. The rapidity of collapse in the necrotic flecks suggested an osmotic disturbance. If the differences between the chlorotic and the necrotic flecks are not basically morphological, then there may be two separate types of protoplasmic resistance based upon the collapse of host cells.

In the minute pustule reaction both rusts survived host cell destruction. Nutrients were probably transported from the healthy tissues at the periphery of the flecks to the cites of sporulation rather than the fungus gaining nourishment from the dead cells. Haustoria were associated with sporulation but were not necessary for hyphal growth, as evidenced by the chlorotic flecks.

On the basis of Stakman and Piemeisel's observations and an accepted classification of rust reaction types (14), both the chlorotic and necrotic flecks are classified as "O;" since no pustules form, yet there is a histological difference which has some genetic basis (16). It is suggested that a subdivision of the "O;" reaction be made for both maize rusts, perhaps "O;C" (chlorotic) and "O;N" (necrotic). These would serve as a better guide to studies of disease resistance.

Other studies of rust histology agree generally with the results presented here. Marryat (10) observed that, in wheat resistant to *Puccinia glumarum* (Schmidt) Erikss. & Henn., rust hyphae had fewer nuclei, appeared watery, and lacked haustoria. Stakman (13) found that the hyphae of stem rust in resistant wheat became closely appressed to the host cells and died to form a homogeneous mass. Allen (2) reported that the nuclei of the first cells attacked by *P. graminis* Pers. var. *tritici* Erikss. and Henn. in Mindum wheat were rapidly destroyed. This could not be shown for the necrotic fleck in maize leaves and was not true in the chlorotic fleck. Hursh (8) discovered that the mycelium of stem rust of wheat was limited to chlorenchyma which was also true for the maize rusts. Hart (6) reported the sclerenchyma cells in wheat as "unyielding" which was true of the border parenchyma and vascular elements in maize leaves. Regarding *P. sorghi*, Wellensiek (17) invoked the "starvation hypothesis" of resistance suggesting that necrosis was nutrient limiting. Results presented here are not strictly in accordance with this view since considerable mycelium was visible in the chlorotic flecks, and in the minute pustule reactions, necrosis did not prevent sporulation.

Regarding *P. sorghi*, the results agree with Mains (9) observations that, in the susceptible reactions, no haustoria were found in the border sheath and the vascular tissues.

Summary

The host-parasite interactions of corn plants resistant and susceptible to the two corn rusts, *Puccinia polysora* and *P. sorghi*, were studied. Resistance was defined as the prevention of sporulation and two symptoms accompanied lack of sporulation, a chlorotic fleck and a necrotic fleck. Both rusts behaved in the same manner. The chlorotic fleck was associated with hyphal growth without haustorial formation, and the host cells in this reaction remained turgid for 7-10 days and then collapsed slowly. The necrotic fleck resulted from the complete and immediate breakdown of host cells in the region of the hyphae. No haustoria were seen, but they may have been obscured by the collapse. These differences within a "O;" type response were given as a basis for subdividing this reaction in order to improve genetic and physiological studies of disease resistance. A third reaction type consisted of a minute pustule formed within a necrotic fleck. Haustoria were observed here and hyphae were more turgid. All reactions were compared to the susceptible example where hyphae grew freely through the tissues, separating cells, and forming numerous haustoria and spores.

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Studies of the Ovule and Seed Development of Guar

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Purdue University

Introduction

Guar (*Cyamopsis tetragonoloba* (L.) Taub.) appears to have great potential as a field crop because of its production of mannogalactan gum. The gum is produced in the seed and is located in the tissue surrounding the embryo. In legumes, the endosperm is commonly digested and absorbed during embryo development so that the mature seed consists only of a seed coat surrounding an embryo. The persistence of a food-storage tissue in the guar seed is of botanical interest as well as of commercial significance. Therefore, the nature of the development of this food-storage tissue has been investigated.

The problem being studied is the morphological development of the guar ovule and seed. Primary concern will be given to endosperm development. Certain aspects of the development of the female gametophyte late embryo stages, and associated parts of the seed are included to show their relationship to endosperm growth.

Methods and Materials

The plant material used in this study was *Cyamopsis tetragonoloba* cv. 'Texsel' obtained from the 1962 Guar Research Field Plot at the Purdue University Agronomy Farm.

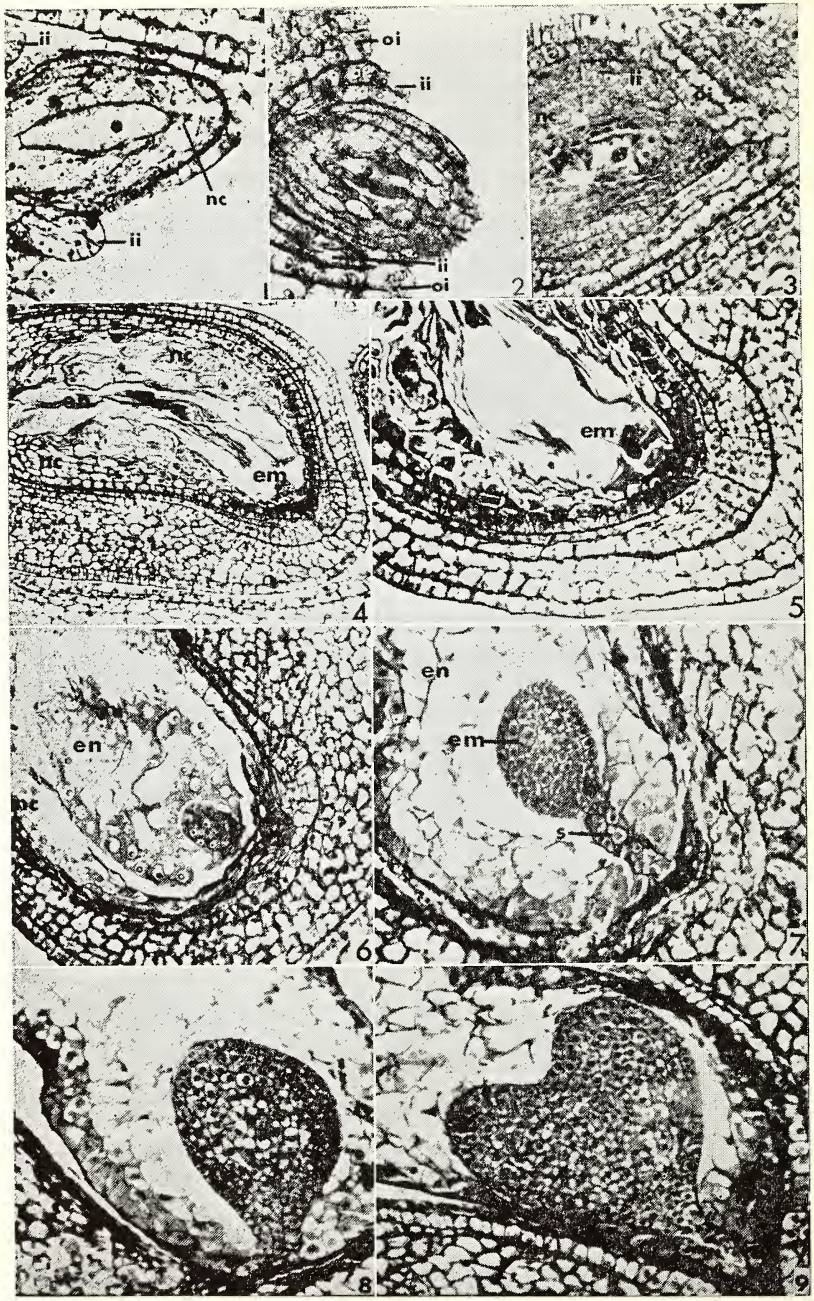
In preparation for sectioning the fresh material was killed and fixed in Randolph's Modified Navishin (Craf) solution (4). After killing and fixation, the material was dehydrated in an ethyl-alcohol to xylol series followed by infiltration with paraffin.

The material was sectioned on a rotary microtome at a thickness of 6-8 micron and stained with a combination safranin and fast green series. Microphotographs were taken on a Zeiss photomicroscope.

Results

Early stages of guar ovule development are found in the young flower bud. The crassinucellate ovule consists of nucellular tissue surrounded by two integuments, supported on a funicular stalk. The embryo sac develops within the ovule, and after fertilization the growing embryo and endosperm eventually fill the guar seed. The nucellus is broken down as the endosperm develops, and by the time the seed matures the nucellar tissue is no longer present. The endosperm persists in the mature seed and the outer integument is modified to form parts of the testa.

INTEGUMENTS: Two integuments are initiated as evaginations at the base of the young ovule and these eventually grow around the nucellus (Fig. 1). Each integument consists of two cell layers that divide anticlinally. The integuments away from the funiculus grow at a more rapid rate than the two integuments nearest the stalk (Fig. 2).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The inner and outer integuments on either side also grow at different paces. Initially the growth of the inner integument appears more pronounced, but as development proceeds the outer one passes it. By the time the female gametophyte has matured (Fig. 3), the edges of the outer integument have met above the nucellar apex, and the edges inner integument have not yet reached this point. About the time of fertilization however, the inner integument forms an envelope around the nucellus, and the meeting of the integuments at the nucellar apex forms the micropyle.

After fertilization the ends of the integuments become closely appressed above the nucellar apex. The outer integument thickens and differentiates (Fig. 4). The inner integument appears to remain only two cell layers thick and does not undergo further differentiation. As development proceeds the two cell layers of the inner integument around the embryo sac becomes less and less distinguishable, except at the micropylar end where the two cell layers can be distinguished through heart shaped embryo stages (Fig. 21).

In the mature seed (Figs. 24, 25) the inner integument has been broken down or resorbed, and it appears that only scattered and fragmented cells remain. The outer integument has been modified as the seed matured to form parts of the seed coat or testa. A mesophyll layer (Fig. 25), which lies near the endosperm, has been formed from the inner part of the outer integument. Hour-glass cells compose the intermediate layer between the mesophyll and the palisade cells. These cells are columnar, like the outer palisade cells, but they are much larger and sometimes appear slightly waisted in the middle. The inner ends appear more irregular in shape than do the outer ends. The palisade cells are slender, tightly packed columnar cells. Their outer ends are covered with a cuticle (Figs. 24, 25).

EMBRYO SAC FORMATION: Within the ovule a single, functional megaspore (Fig. 1) survives and eventually grows into the embryo sac. This functional megaspore undergoes mitotic divisions to form a monosporic, 8-nucleate female gametophyte structure (Fig. 3). Two synergids lie on either side of the egg cell at the micropylar end of the embryo sac. Three antipodal nuclei occur at the chalazal end, and two

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Figures on ovule and embryo development, 1-9: 1. Early stage of the young guar ovule found within the flower bud. A massive nucellus (nc) surrounds the surviving functional megaspore. Inner (ii) and outer (oi) integuments have evaginated from the base of the ovule. X430; 2. A young guar ovule showing the growth of the integuments around the nucellus. X380; 3. The 8-nucleate female gametophyte of guar. A massive nucellus (nc) surrounds the embryo sac. The outer integuments (oi) have reached the nucellar apex. The inner integuments (ii) have not yet reached the apex. X370; 4. Early globular embryo (em) soon after fertilization. Free nuclear endosperm (en) is spread through the embryo sac. Nucellar tissue is still prominent. X90; 5. Early globular embryo (em) showing free endosperm nuclei. X320; 6. Globular embryo surrounded by free nuclear endosperm (en). X250; 7. Late globular embryo (em) with suspensor (s). Early cell wall formation in the embryo. X300; 8. Late globular embryo just before cotyledonary regions become prominent and cellular endosperm. X250; 9. Heart shaped embryo. Cotyledonary regions are clearly distinguishable. X225.

polar nuclei are located in the center of the sac. The mature ovule at this time is in a campylotropous position.

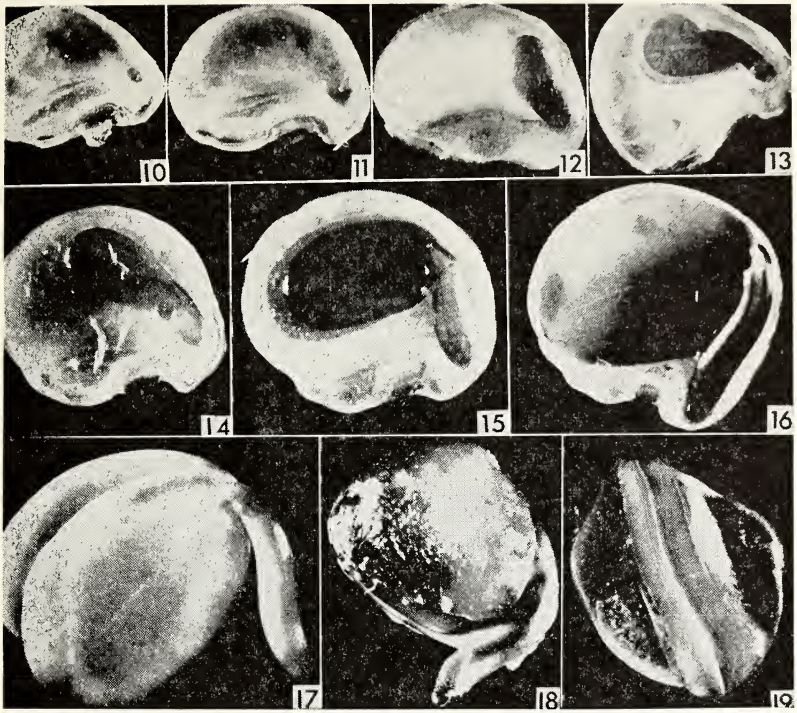
THE NUCELLUS: As the embryo sac develops it is surrounded by a massive nucellus whose several cell layers separate the sac from the nucellar epidermis (Figs 1, 2, 3). As the endosperm tissue expands it does so at the expense of the nucellus. A sequential comparison of all stages from soon after fertilization (Fig. 4) to the time of maturity (Figs. 23, 24, 25) shows that the nucellus is ultimately broken down or resorbed. Right after fertilization, when the endosperm is still all free nuclear, most of the nucellus is still present (Fig. 4). By the heart shaped embryo stage most of it has been broken down (Fig. 21), and by later stages (Fig. 22) only a very few, if any, nucellar cells remain.

THE EMBRYO: Very early divisions of the embryo have been thoroughly worked out by Anataswamy Rau (2) and therefore have not been a major concern of this study. According to Anataswamy Rau the zygote divides transversely to form a basal cell and a terminal cell. The basal cell subsequently forms the suspensor supporting the embryo, and the terminal cell develops into the embryo proper.

Later events in the development of the embryo in this study can be described in sequential stages according to embryo shape. The terminal cell gives rise to a globular stage by a series of anticlinal and periclinal divisions (Figs. 4, 5, 6). As divisions proceed the embryo becomes less globular; height and breadth are approximately equal, but it is somewhat flattened in the third dimension (Figs. 7, 8). Divisions in the suspensor do not keep pace with those of the embryo proper (Fig. 7), resulting in fewer but larger cells. The hypophyseal part of the embryo, which gives rise to the extremity of the root and root cap, is initiated at the very base of the embryo, just above the area of attachment with the suspensor (Fig. 7). Further divisions in the procotyledonary region (Fig. 8) produce the heart shaped stage (Fig. 9), where the cotyledonary parts become clearly distinguishable.

After the heart stage the cotyledons undergo longitudinal growth (Figs. 10, 11) until a 'torpedo' stage is formed (Fig. 12). At this stage the hypocotyl appears lengthened and is almost as long as the cotyledons that have flattened against each other. As further growth occurs the cotyledons turn back within the ovule (Figs. 13, 14). Later the cotyledons and hypocotyl lie almost at right angles to each other (Fig. 15), and at seed maturity the embryo (Figs. 16, 17) has almost completely filled the seed. The cotyledons and hypocotyl lie very close to the edge of the testa (Fig. 16). Chlorophyll was observed in the embryo from the later heart shaped stages to the time of maturity.

THE ENDOSPERM: A nuclear type of endosperm is initiated at the time of fertilization by the fusing of a sperm nucleus and the two polar nuclei. The 3n nucleus undergoes a series of mitoses shortly after fertilization. At first free endosperm nuclei become distributed somewhat evenly through the embryo sac (Fig. 4). A short time later the free nuclear endosperm appears more concentrated around the embryo (Fig. 6). The embryo at this time is in a globular stage.



Figures on embryo and see development, 10-19: 10. Heart shaped embryo within immature seed. X21; 11. Late heart shaped embryo. X19; 12. "Torpedo" stage embryo. X17; 13 and 14. Later embryo stages. The cotyledons have begun to turn back within the ovule or the immature seeds. X16; 15. Late embryo, just before maturity. X14; 16. The embryo within the mature seed. X13; 17. The mature embryo that has been removed from the seed before drying has occurred. X10; 18. The mature embryo surrounded by endosperm. X13; 19. Cross section of the mature seed before drying has occurred. X14.

Cytokinesis is initiated in the endosperm at the micropylar end of the embryo sac near the embryo (Fig. 7). This cell formation extends toward the chalaza until most of the endosperm is cellular. However apart from this main body of cellular endosperm many free endosperm nuclei can be seen at the chalazal end (Figs. 20, 21) until the embryo has reached the heart shaped stage (Fig. 21). After this time the number of free endosperm nuclei evidently gradually diminish and degenerate. A free nuclear tubular portion is often visible at the tip of the main body of endosperm (Fig. 20).

The outer layer of the main endosperm body is composed of small cells, while the cells of the interior are larger and have thinner walls. The cells of the outer layer are more dense and stain darker at all stages (Figs. 7-9, 20-25).

THE MATURE SEED: In the mature seed the nucellus has been broken down or resorbed and the endosperm completely surrounds most

of the embryo (Figs. 18, 19, 23) and the outer border of the endosperm lies next to the testa (Figs. 24, 25) that developed from modifications of the outer integument.

At maturity, just before the seed begins to dry, the endosperm appears almost transparent (Figs. 18, 19) and it comprises the bulk of the seed. Upon drying the endosperm becomes more opaque.

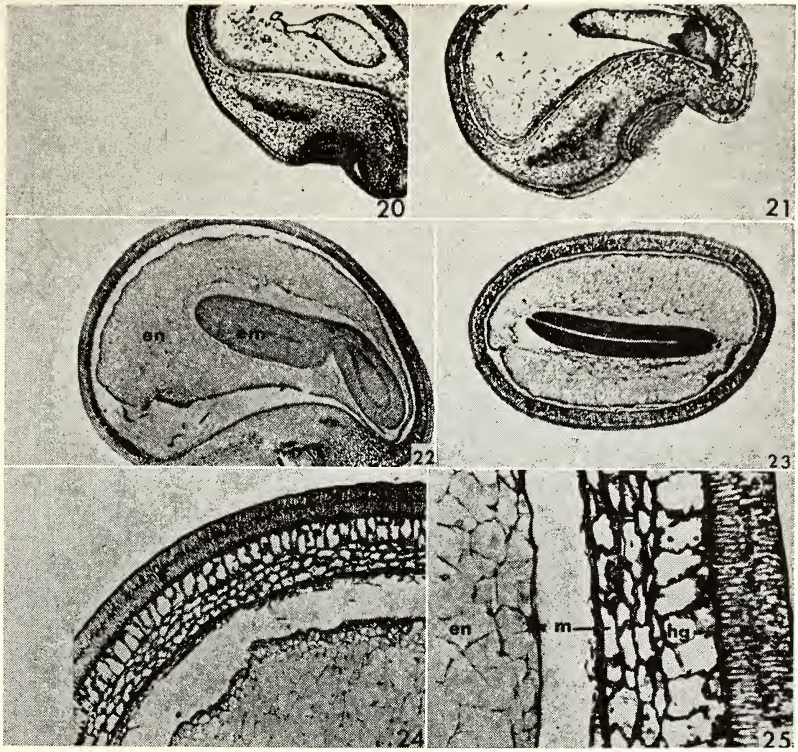
Discussion

Anataswamy Rau (2) has carefully diagramed the successive cell divisions in the embryo development of guar from the two-celled proembryo stage through the early globular stages. The epiphyseal, cotyledonary, hypocotyledonary, and hypophyseal regions were pointed out in the stages he presented. The evidence presented here (Figs. 4, 5, 6) on early embryo development agree with several stages diagramed by Anataswamy Rau (2).

Johansen (5) has outlined the details of the Trifolium Variation, a basic type of embryo development. It appears that Anataswamy Rau has assigned *Cyamopsis psoraloides* to the Trifolium Variation largely on the basis that the early divisions of this embryo conform to those of *Trifolium minus*. The study presented here was not mainly concerned with the successive divisions of the early embryo, but it does show evidence that the suspensor of this embryo conforms to the Trifolium Variation by having a suspensor whose cells differ from those of the body of the embryo in form, number, and plane of division (Fig. 7). Therefore, on the basis of the work of Anataswamy Rau and evidence presented in this study, the early embryo development of guar appears to largely conform to the Trifolium Variation as outlined by Johansen.

Anataswamy Rau (1) presented an analysis of the early endosperm development in guar and several related species. The results on early endosperm formation, and ontogeny for guar presented here largely support the analysis done by Anataswamy Rau on this species. Anataswamy Rau mentioned the presence of a free nuclear tubular portion at the tip of the main body of endosperm, or in the chalazal portion, during early stages. He did not give reference to any comparable stage of embryo development when this tubular portion was present. However, in this study a free nuclear portion at the tip of the main body of endosperm (Fig. 20) was observed only during late globular-early heart shaped stages of the embryo. Possibly it was also present at earlier stages; but due to the delicate structure of this tubular portion, it might have been destroyed in sectioning.

Corner (3) stated that two microscopic characters distinguish the leguminous testa: 1) the external palisade, developed from the outer epidermis of the outer integument, and 2) the hour-glass cells, developed from the outer integument. According to Corner any testa with these two microscopic features is apparently leguminous. A magnified section of guar testa from the side of the seed shows these two characteristics and identify the testa as being leguminous (Figs. 24, 25). Corner further stated that hour-glass cells having inner ends that are very irregular are often characteristic of Papilionaceae. This characteristic



Figures on embryo and seed development, 20-25: 20. Longitudinal section through the immature seed at a late globular embryo stage showing a portion of cellular endosperm and a free nuclear tubular portion at the tip of the main body of endosperm. X35; 21. Longitudinal section of the immature seed at a heart shaped embryo stage showing the cellular endosperm body surrounded by free nuclear endosperm. X30; 22. Longitudinal section of the immature seed at a later embryo stage (em) showing the cellular endosperm (en) which surrounds the embryo. X35; 23. Cross section of mature seed showing cotyledons, endosperm, and testa. X30; 24. Section of the mature seed showing a portion of the endosperm and testa. X90; 25. Enlarged section of mature seed showing endosperm (en) and a portion of testa from the side of the seed. Testa structure: mesophyll layer (m), hour-glass cells (hg), and palisade cells (p). X180.

also appears in the hour-glass cells of guar (Fig. 25), and helps to place it in this sub-family.

Summary

Some morphological aspects of the developing ovule and guar seed are described. Emphasis is placed on endosperm development. The endosperm is important as a source of mannogalactan gum, and the fact that the endosperm persists in the mature guar seed is an unusual situation for a leguminous species.

The guar ovule is found within the flower bud and consists of a massive nucellus surrounded by two integuments. Within the ovule a

monosporic, 8-nucleate female gametophyte is formed. After fertilization the nucellus is gradually broken down or resorbed as the endosperm develops, and at seed maturity the nucellar tissue is not present. The inner integument remains only two cell layers thick, and it is evidently broken down or resorbed before the seed matures. The outer integument becomes complicated to form various parts of the testa. The cell structures of this guar testa from the side of the seed compare favorably to the testa cell structure of other species of Papilionaceae.

Early stages of embryo development were found to be similar to early stages of the basic Trifolium Variation, and descriptions of Anataswamy Rau (1). Later stages of embryo development are described according to embryo shape. Throughout most of its development the embryo is almost completely surrounded by endosperm.

A nuclear type endosperm is initiated at fertilization. During early stages many free endosperm nuclei are distributed through the embryo sac. A short time later the free endosperm nuclei are more concentrated in the area around the embryo. Cytokinesis is initiated during globular stages and progresses from the micropylar to the chalazal end of the embryo sac. Free endosperm nuclei persist in the chalazal end even after cytokinesis is initiated. A free nuclear tubular portion was observed at the tip of the main body of endosperm during late globular-early heart shaped embryo stages. At seed maturity the endosperm surrounds the embryo and it comprises the bulk of the seed.

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The Holdridge Bioclimatic Formations of the Eastern and Central United States

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Introduction

The Holdridge system has been proposed as one capable of defining equally weighted and comparable divisions of the biosphere using climatic parameters, biotemperature, precipitation and potential evapotranspiration ratio.

Working on the vegetation of Haiti, Holdridge (1) found the need for a system of classification that would show relations of Haitian plant communities to the vegetation of other areas. His search of the literature revealed a general consensus that the major causes of climatic differences in vegetation are temperature and precipitation. From a background of field observations and corresponding temperature and precipitation data, Holdridge produced ". . . a graphic chart which immediately shows a rhythmic and logical spatial relationship between natural plant formations."

Since that time Holdridge has continued work in the tropics. Using his system (2, 3), he and others supported in part by the Organization of American States have mapped the life zones of several Central American and South American countries. Countries with completed, published maps include Panama, Guatemala, Costa Rica and El Salvador (4). Tosi (5) has also published a map and monograph on Peru based upon the Holdridge system. A map of Colombia is in press.

This approach proved very useful in ecological and land use mapping in the American Tropics, but it had not been applied elsewhere. The object of the present study is to further clarify the Holdridge system by use of a three-dimensional model, and to map part of the United States by strict use of Holdridge's climatic criteria alone. The resulting map may enable biologists, geographers and climatologists to judge from their diverse viewpoints the possible usefulness of the Holdridge scheme for their various purposes.

Three-dimensional Model

The major unit of the Holdridge system is the life zone or bioclimatic formation, characterized by its climatic association. Other association types (edaphic, hydric, etc.) may also be present within the bioclimatic formation (3). The formations are defined by biotemperature, precipitation and potential evapotranspiration ratio values (2, 3). Two diagrams are used in classifying any given station. The data required for classification are normal mean annual biotemperature, normal annual precipitation and altitude.

1. The writers thank Dr. Leslie R. Holdridge and Indiana State Climatologist Lawrence Schaal for aid.

Biotemperature, found most simply by adding normal monthly temperatures above 0°C and dividing by 12, is a function of latitude, but this relation is complicated by elevational differences. Biotemperature represents a convenient integrative device for expressing the combination of climatic parameters which determine the heat factor. These include thermoperiod, photoperiod, and the angle, intensity and quality of solar radiation.

Since latitude and elevation interact to determine the normal annual biotemperature at a station, a three-dimensional relationship exists among them and the humidity factor. This three-dimensional relationship is inherent in the two charts by Holdridge, but is more easily seen in a

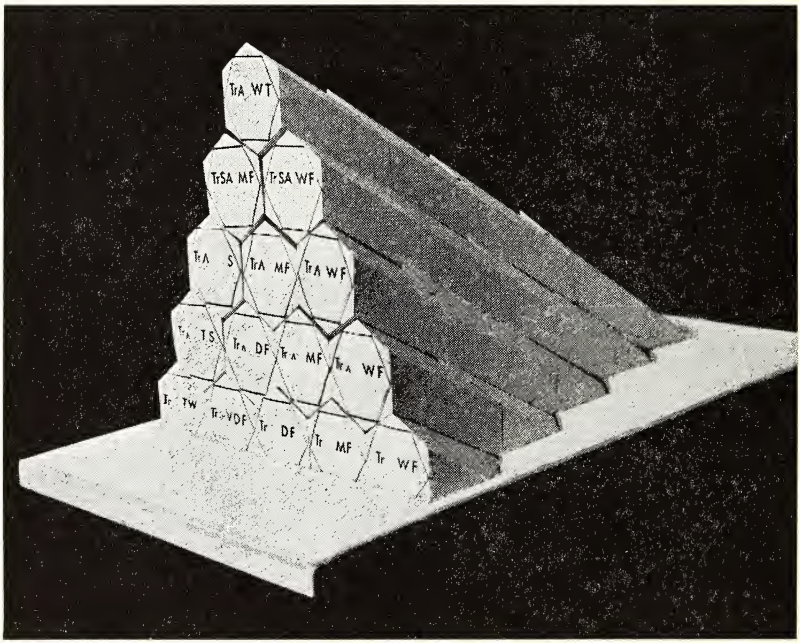

Figure 1. The complete model showing the three-dimensional expression of the diagrams made by Holdridge. Only part of the Holdridge's "Bioclimatic Formations of the World" chart is shown. Each distinguishable unit represents a bioclimatic formation, but only the names of the Tropical formations are seen. Tr—Tropical, Λ—Lower Montane, Λ—Montane, SA—Subalpine, A—Alpine, WT—Wet Tundra, WF—Wet Forest, MF—Moist Forest, DF—Dry Forest, S—Steppe, VDF—Very Dry Forest, TS—Thorn Steppe, TW—Thorn Woodland.

three-dimensional model made by Sawyer (Figure 1). Each axis of the model is logarithmic on the base 2.

Latitudinal regions progress back from the heat equator (lettered face of the model) toward the polar region. These latitudinal regions are Tropical, Warm Temperate, Cool Temperate, Boreal and Polar. Each latitudinal region is composed of a basal or sea level region named for the latitudinal region and various altitudinal belts (Lower Montane, Montane, Subalpine, Alpine and Nival). The presence of the altitudinal

belts depends on the latitudinal region; Tropical has all the above mentioned, but Boreal has only Alpine and Nival. The third dimension, moisture, is classified by humidity provinces. The range in the Tropical region is from superarid to superhumid, but only superhumid to semiarid in the Subpolar region due to less potential variability with lower temperatures. Vegetationally the humidity province is often identified by adjectives, e.g., Moist Forest for the humid province and Dry Forest for the subhumid province. This can be seen on the face of the model in Figure 1. Wet Forest (WF) runs up and to the left in the latitudinal belts of the Tropical region as well as back and to the left in the latitudinal basal regions (see right-hand base of model) giving continuity among the model parts.

A given physiognomic type can occur in more than one latitudinal region. Steppe, as defined by biotemperature, precipitation and potential evapotranspiration ratio values, may occur in three latitudinal regions (Figure 2). In the Cool Temperate region (Figure 2A) steppe conditions

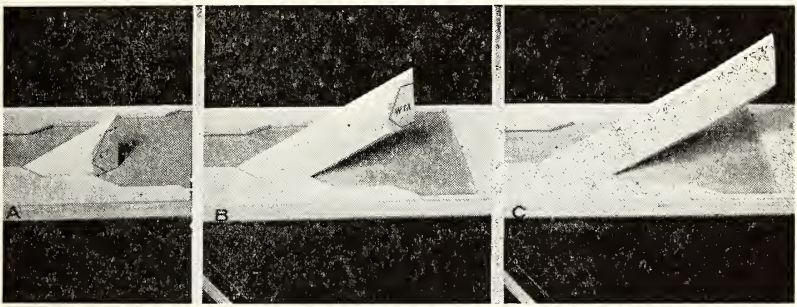

Figure 2. The three Steppe formations are shown here. All three are defined by the same biotemperature, precipitation and potential evapotranspiration ratio values, but differ in altitudinal and latitudinal relations. The Steppe formations occur in three latitudinal regions. In the Cool Temperate region, steppe conditions are found at sea level, as shown in A. In the Warm Temperate region, the steppe formation is found in the Montane belt, part added in B. In the Tropical region another Steppe formation is also found in the Montane belt, part added in C. CT—Cool Temperate, WT—Warm Temperate Montane.

exist in the basal region where elevation does not complicate the latitudinal pattern. In the Warm Temperate (2B) and Tropical regions (2C), steppe conditions can exist in the Montane belt. That is, cool temperate-like conditions can occur in Warm Temperate and Tropical regions at elevations above sea level. But the conditions still differ enough due to factors varying with latitude and altitude to result in different climates and therefore different bioclimatic formations. Further discussion and figures of the model and a review of that part of the literature on the Holdridge system published in English may be found in Sawyer (6).

Methods for Mapping

The Holdridge system was applied to the part of the United States east of the Rocky Mountains. All or part of 37 states were included. The 102°W meridian was chosen as the western boundary. The eastern

half of the United States was used because of its rather uniform topography, as compared to the West. Since no field work would accompany the mapping, this area was chosen because its network of Weather Bureau stations was considered adequate. Approximately 1400 stations were used.

In mapping the bioclimatic formations, Weather Bureau stations with sufficient data were classified as to their position on the two charts. These data tabulated by states have been fully presented elsewhere (6). The station, its biotemperature, annual precipitation, elevation and bioclimatic classification are given. The stations were classified using the data from *Climates of the States.* U. S. Weather Bureau, 1931-1955. The station elevation was obtained from *Climatic Summary of the United States, Supplement for 1931 through 1952* in the table, "Station Index and History." If the station had been moved during its history the elevation of the last location was used.

The stations were located on the appropriate Sectional Aeronautical Chart and their classification was marked at the town's name. These (7) charts were used in the initial mapping. Their scale (1:500,000) is large enough to show major relief and to give the small towns, yet small enough to be easily handled. Their major use is for contact flying by slow-medium speed craft, but served our purpose admirably.

When all the stations were located and annotated, the boundaries between the bioclimatic formations were easily drawn. Surprisingly little smoothing of the lines between formations was needed. If one or two stations were not in accordance with most of the surrounding stations they were disregarded. In most cases there were enough stations in sufficiently close proximity to determine whether a station was an exception.

The Warm Temperate latitudinal region is subdivided into two subregions, Low Subtropical and Warm Temperate. The important difference between the two subdivisions is the frequency of severe killing frosts. The occurrence of severe killing frosts is a regular phenomenon in warm temperate conditions, but not in subtropical conditions. This climatic factor determines the presence or absence of broadleaved evergreen trees and other tropical vegetation, thus determining the character of the vegetation.

The Subtropical region is defined as an area within the Warm Temperate region having the probability of one severe killing frost (28°F or —2.22°C) in any one year of less than 33%. The Warm Temperate Subregion is that area having a probability of killing frost greater than 33% (personal communication, Holdridge, 1962). Any given station classified in the Warm Temperate latitudinal region by the biotemperature and precipitation data can be classified either as Warm Temperate or Low Subtropical depending upon the presence or absence of frost as part of the normal climatic regime.

To determine the position of the line separating the Warm Temperate from Low Subtropical, the percentage of years having one or more killing frost for a given station was determined. A preliminary survey of frost occurrences in the South was done using the "Killing Frost Data" table in *Climates of the States* for Florida, Texas, Louisiana,

Alabama, Mississippi and Georgia. It was determined that only in central and southern Florida was the frequency of frosts in the spring (January 1 on) less than one season in three. Due to the fact that the data in this table were not adequate for this use, the *Annual Summary of Climatological Data for Florida* was consulted for the years from 1931 to 1956. Using "Temperature extremes and Freeze Data" table for the threshold of 28°F, the number of years in which one minimum temperature of 28°F or lower occurred was determined. Stations with a relative frequency of frost occurrence of 32.9% or less were classified Low Subtropical, and those with 33% or greater Warm Temperate.

Results

Eleven of the life zones were extensive enough to be shown on the map (Fig. 3). The existence of others is indicated by the station on Mount Washington, N. H., classified as Warm Temperate Alpine Rain Tundra. Since most stations are in valleys, life zones at high elevations were not well represented.

Four latitudinal regions were mapped in the eastern and central United States—Tropical, Low Subtropical, Warm Temperate and Cool

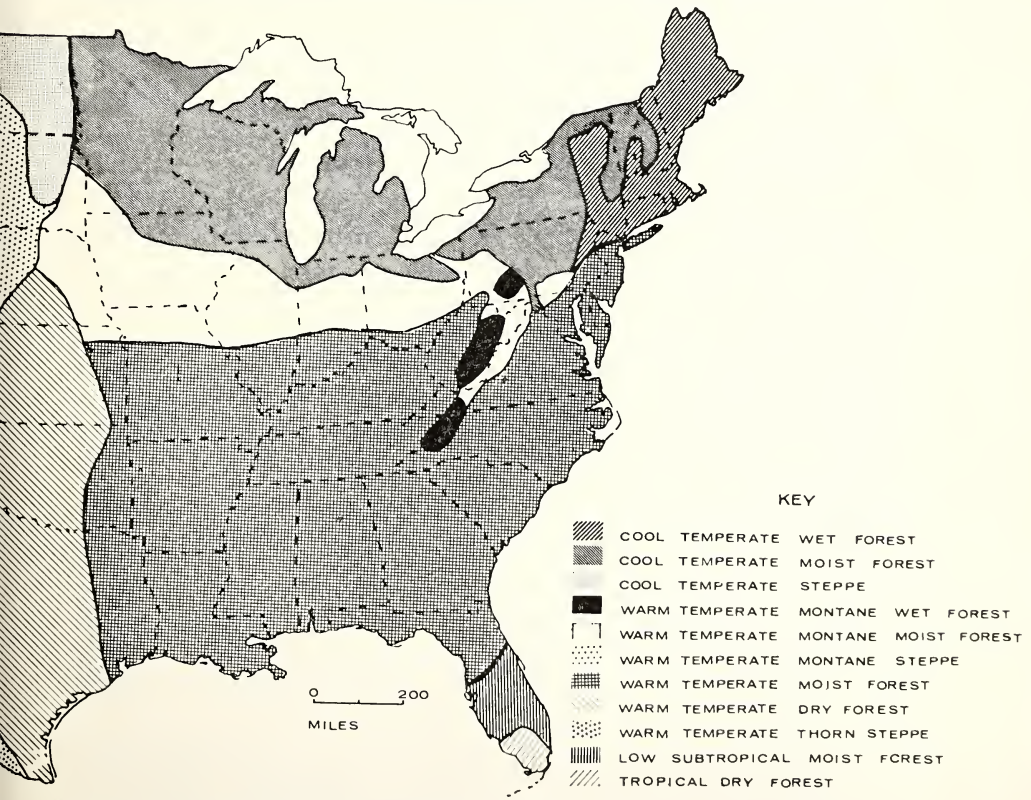

Figure 3. The bioclimatic formations of eastern and central United States, derived by application of the Holdridge system.

Temperate. The Tropical region was found only in the southernmost tip of Florida and is characterized by Dry Forest. In central Florida there is a small area of Low Subtropical Moist Forest. The Warm Temperate region is characterized by three vegetational types, Dry Forest, Moist Forest and Thorn Steppe. Warm Temperate Moist Forest covers the greatest area of any of the bioclimatic formations; its westernmost boundary is in eastern Texas, Oklahoma and Kansas where it gives way to Dry Forest. Warm Temperate Dry Forest is a rather narrow north-south band in Texas, Oklahoma, Kansas and Nebraska. To the west of the Dry Forest is Warm Temperate Thorn Steppe.

North of the Warm Temperate region (basal area) lies the Montane belt of the Warm Temperate region. In the central and southern Appalachian region Montane Wet Forest and Montane Moist Forest are found as altitudinal belts.

The initial reaction to a Montane belt crossing the Midwest is that the region is not mountainous. But, seen in Figure 2, the Warm Temperate Montane section like all other altitudinal belts actually continues to the base line, i.e., sea level. Therefore, it would be expected to reach down to low elevations in areas of transition between two latitudinal regions as is found in the Midwest.

Warm Temperate Montane Moist Forest continues west from Pennsylvania, across Ohio, Indiana, Illinois, Iowa (cf. 8) and into the eastern portion of Nebraska and South Dakota. Here it changes to Warm Temperate Montane Steppe which covers much of South Dakota, Nebraska and smaller areas of North Dakota and Kansas.

Three bioclimatic formations are found in the Cool Temperate Region—Wet Forest in eastern New York and most of New England. Moist Forest from New York and Pennsylvania to Minnesota, and Steppe in the eastern part of North and South Dakota.

Discussion

While it is of some interest to compare (6) Figure 3 with various maps of climate (9, 10) and vegetation (11, 12) of the region, it seems doubtful that this would constitute a valid "test" of the Holdridge system. The reader's evaluation of this system may depend more upon his background and viewpoint than upon the objective findings presented above. Rather than discuss or criticize the system from a given viewpoint, it seems more helpful to offer certain precautions to the reader who may himself judge its usefulness, if any, for his purposes.

Figure 3 is obviously not a map of actual vegetation types, and should not be expected to conform with such maps, which differ among themselves in theoretical and classification bases. According to Holdridge (personal communication, 1963):

> "The life-zone system does not or should not pretend to delineate homogeneous communities or associations of vegetation. The life-zone is a climatic division defined by biotemperature, precipitation, potential evapotranspiration and elevation in a logarithmic system which makes all life-zones equivalent in significance. Within each life-zone there may be several vegetation associations dependent on soils, lesser climatic variables and the presence or absence of open

water. The one climatic association of each life-zone wherein none of the secondary variations are significant, corresponds to a zonal soil and zonal climate. This, of course, may or may not be present in an area where the life-zone is present, but since the physiognomy of the climatic association most clearly typifies the life-zone it has been utilized on the chart as a name for the life-zone."

Thus, the tall grass prairie, a type of vegetation of undeniable importance in this country, is absent in Holdridge's present classification, as it fails to meet the criteria given. But when life-zone boundaries are placed objectively in accordance with climatological data, their implications as to the reasons for an apparent discrepancy may help in reaching a proper interpretation of the factors responsible for the physiognomics of the existing vegetation. Other discrepancies may, of course, be real. Not all ecologists are likely to agree with Holdridge's (personal communication, 1963) interpretation of the several low vegetation types actually present in the mapped Warm Temperate Dry Forest as resulting, in a dry forest climate, from protracted disturbances such as fire, early man, and grazing. Hence, differences in opinion as to the theoretical climax of a region may affect evaluation of the system. Southern Iowa appears to come out wrong in Figure 3 to those who consider bluestem prairie as the climatic climax there, but not to others who regard Iowa as having in reality a moist forest climate.

"There is no sound reason to presume that any one of the several classificatory maps correctly portrays the climate-vegetational relationship, or that Holdridge's model is valid or invalid, approximate or precise, simply because it accords or fails to accord, in whole or in part, with the distribution as depicted by other generalized classifications." (Personal communication, Dr. Joseph Tosi, 1963).

Again, is it possible to test the Holdridge system by comparing our Figure 3 with such generalized climatic maps as Thornthwaite (9) or Trewartha's (10) modification of Köppen? It is uncertain whether such comparisons are testing the Holdridge scheme or the others. Holdridge's concept is a broadly synthesizing one intended for the biosphere as a whole, whereas our application involves a relatively small geographic area.

The system may be regarded from either the traditional ecological conception of types, or from the continuum viewpoint. For some ecological purposes, the regions, belts, provinces, and climatic association names can be disregarded, and the present hexagon boundary lines (5) not accorded special significance. The remaining three-axis skeleton graph, showing gradients of precipitation, biotemperature, and evapotranspiration, provides a meaningful framework for certain ecological analyses, such as plotting limits of the geographic range of an entity in relation to these important climatic parameters.

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The Effect of Peat-moss Extracts on Seed Germination

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Peat-moss—the partially decomposed remains primarily of *Sphagnum* species—is a standard potting material for several classes of plants as well as being the preferred medium in the moist cold treatment (stratification) of the seeds of many types of ornamental and forest tree species. During stratification a seed may double its weight by imbibing what is essentially an aqueous steep of the surrounding peat-moss.

Gardners, nurserymen, and others have long held that contact with peat-moss may actually improve seed germination and early root growth and that the peat-moss may have fungicidal properties as well. The vegetal origin of peat-moss, of course, suggests it to be able to supply a wide range of inorganic and organic compounds to its surroundings. Furthermore, certain reports in the scientific literature provide support for the observations that have been made, among them the following.

On the basis of both straight-growth and root-initiation bioassays, Niggemann (2) reported aqueous extracts of peat-moss to contain growth promoting and inhibiting substances, including indoleacetic acid. Additionally such extracts appeared to contain the enzymes required to convert tryptophan to indoleacetic acid. They were also found by him (3, 4) to contain oestrus-stimulating compounds, these perhaps coinciding with the plant growth inhibitors he had described previously. Niggemann (2) also referred to other reports in the literature of peat-moss containing a variety of growth stimulators, oestrogens, and antibiotics. Recently Pokorná (5) demonstrated catalase activity in peat-moss derived from *Sphagnum palustre* L. Květ (1) found that the water-soluble components of peat-moss promoted the growth of the alga *Chlorogonium euchlorum* Ehrenberg.

The various indications that peat-moss is capable of supplying growth-influencing substances to its surroundings led us to observe the possible effect of a peat-moss steep on the germination of certain seeds.

Materials and Methods

The seeds of two divers species were tested: lettuce (*Lactuca sativa* L. cv. Grand Rapids) and jack pine (*Pinus banksiana* Lamb.). All germination tests were performed in blocks of 50 seeds which were placed dry on a substratum of six thicknesses of Whatman No. 1 filter paper in covered 9-cm. petri dishes. Each dish was moistened with either 10 ml. of distilled water or test solution. The design, number of replications, and general procedure made the results amenable to statistical analysis. Incubation was carried out at ca. 22°C; continuous dim red light (wave lengths longer than ca. 660mμ) was provided for the satisfaction of any light requirements. Prior to incubation the jack pine seeds were maintained at ca. 5°C for 72 hours in their moistened petri dishes.

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The steep tested was obtained by immersing 428 gm. of air-dry peat-moss (Detorf Co., Bremen, West Germany) in 3,500 ml. of distilled water, an amount just sufficient to cover it. The peat-moss was permitted to soak for 96 hours at ca. 4°C, after which the steep was filtered through Whatman No. 5 paper. A portion of this steep was concentrated ten-fold under reduced pressure. One milliliter of test solution was thus derived from either 0.12 or 1.2 gm. of peat-moss. The pH value of the weaker solution was 4.3 and of the stronger 3.7. Such differences in pH value were found in preliminary tests to have no significant effect on the germination of the seeds used.

Germination percentages were obtained after four days of incubation for lettuce and after seven for pine, the results thus reflecting primarily total germination rather than rate of germination.

Results

The lettuce seeds that were provided with water alone exhibited 86% germination; an analysis of variance showed that the germination of the seeds permitted to imbibe either concentration of the peat-moss steep was not significantly different. The results are summarized in Table 1.

In the case of the jack pine seeds, the treatments did have a marked stimulatory influence. While control germination was 26%, imbibition of the less concentrated steep resulted in 33% germination, and imbibition of the more concentrated steep 48%. An analysis of variance followed by Tukey's comparison of means demonstrated each of the three values to be significantly different from the other two at the 1% level. These results are also summarized in Table 1.

TABLE 1. Effect of imbibed peat-moss extract on seed germination

Species	Concentration of Imbibed Steep (gms/ml)	Germination (%)
Lactuca sativa	0	85.5
	0.12	90.9
	1.2	86.3
Pinus banksiana	0	25.8
	0.12	32.6
	1.2	47.8

In this connection, the data of Rubtzov (6) show that the soaking of Scotch pine (*Pinus sylvestris* L.) seeds for two to five weeks in water collected from a *Sphagnum* bog increasingly inhibits their subsequent germination, but suggest that a five or ten day soak may increase the rate and final percentage slightly.

Conclusion

It has been shown that substances can be steeped out of peat-moss which are capable of influencing the germination of some seeds. Thus when the porous, moisture-holding properties of peat-moss are taken

advantage of to supply water and air to plants being propagated, one must recognize that the peat-moss may be influencing the propagules in more subtle ways as well.

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The Prairie Peninsula as a Filter Barrier to Postglacial Plant Migration

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The wedge of persistent grassland plants and plant communities that extends into the deciduous forest eastward across Illinois and into parts of Indiana, Michigan, Ohio, and Kentucky is still poorly known with respect to its time of origin and its phytogeographic history. This study is an attempt to apply some evidence from pollen diagrams to these problems.

It appears that Gleason (6) was the first to identify the Prairie Peninsula, although it was Transeau (23) who gave it this name and defined its geographic boundaries (shown in generalized form in Figure 1) and climatic characteristics. Gleason showed remarkable insight in identifying this feature from floristic evidence. In the arguments by which he laid down the outlines of post-glacial history of vegetation in the Middle West, Gleason ascribed the origin of this eastward extension of grassland vegetation to an earlier period of greater dryness. He believed that the regional climate was drier during the Wisconsin glaciation, but that the eastward penetration of grassland probably occurred in the wake of northward migrating conifer forests and before the deciduous forests entered the deglaciated region from the south and southeast. He envisaged the grassland elements occupying dry hilltops and other xeric sites, mesophytic and hydrophytic forest pushing into the deglaciated region along stream valleys, and oak-hickory forest resulting from xerarch succession on the intermediate sites. He postulated two avenues of deciduous forest invasion from a "southern Alleghenies" (Central Appalachian) origin: one extending westward as far as the Ozarks, the other passing northwestward to Minnesota, with more recent general northward and westward advance between these two routes in response to a later post-glacial gradual increase in rainfall. Two deciduous elements were involved: ". . . one moving from the Ohio valley and one from the Allegheny Mountains." Gleason believed that Indian-set prairie fires then reduced the extent of deciduous forest to the condition found at the beginning of European settlement early in the nineteenth century, when afforestation again took place until checked by cultivation of the land.

About 1930 a post-glacial climatic optimum was being confirmed in Europe through studies of peat deposits and their fossil pollen. This concept was soon brought to North America, and was subsequently developed (19) into an explanation for expansion of grasslands at the expense of forests in the Interior of North America, including the eastward extension of grassland that is the subject of this discussion. Transeau (23) presented the most informative single account of this feature he called the Prairie Peninsula. He was convinced, on the basis of evidence from fossil pollen and other sources of "a late postglacial

prehistoric dry period with more wide spread drought conditions and more prolonged droughts than at present." He thought that, "If pollen studies of the upper layers of peat within the Peninsular region fail to show a period of this kind either the methods of pollen analysis or the assumptions upon which they are based need further investigation." However, all subsequently published pollen diagrams from Ohio, Indiana, and southern Michigan have failed to produce such evidence, at least that we have been able to recognize. Transeau's distribution maps for tree species such as *Fagus grandifolia* (beech), *Tsuga canadensis* (Canadian hemlock), *Pinus strobus* (white pine), *Liriodendron tulipifera* (tulip poplar), and *Thuja occidentalis* (arbor vitae) could as well suggest that these species were obstructed in crossing the Prairie Peninsula in early post-glacial time as that they were driven back in more recent time.

In 1957 I discussed ambiguities of Prairie Peninsula pollen diagrams with the late Theodore Just, who agreed that we might well look for evidence of an earlier post-ice origin of the feature. We took the problem to Karl P. Schmidt, who has also since died, and found he continued firm in his belief that most of the evidence pointed to an early post-ice origin. He had concluded that at least 11 species of amphibians and reptiles (no less than 6 of which are endemic to this "steppe peninsula") achieved their present ranges by reason of eastward development of the peninsula in the earlier postglacial when "the area was for a time relatively empty of animal life, so that the normal barrier of a saturated fauna was temporarily absent" (17). Philip W. Smith (21) made an extensive review of terrestrial vertebrate distributions related to the Prairie Peninsula, using the range patterns and trends in geographic variation as evidence to support his postulated changes in climate and shift in the eastward extent of the Peninsula. He distinguishes the postglacial Climatic Optimum (warm, humid, with mesophytic trees predominant in pollen spectra) from a subsequent Xerothermic interval, "during which time mesic forest habitats shrank to the east, north, and south of encroaching oak-hickory forest and expanding grassland habitats." This relatively recent dry interval, he believes, can account for disjunct populations of several grassland vertebrates now isolated on the Atlantic Coast. Schmidt had called this route to the Atlantic coast watershed the "steppe corridor" but implied it was early post-ice in age.

Potzger, with his colleagues and students, made a series of studies that established the composition and extent of the pre-settlement and modern forest types in Indiana and especially in the seven northwestern "prairie counties" (14). These studies revealed the predominance of beech forests in central and south-central areas, of oak-hickory forest in northern, northwestern, and southwestern areas, and oak openings with prairie stands only in the northwestern corner and on the western boundaries of Indiana.

Potzger and Friesner (13) made an early and revealing analysis of post-glacial forest history in Indiana by comparing the stratigraphic appearance and disappearance of 11 tree genera in pollen records of 7 bogs in central Indiana (Marion County north to southern Cass County).

It is of interest here that *Fagus* was not recorded at all from 3 of the bogs, appeared well after *Acer* in 3, and appeared before *Carya* only in 1 (Emporia, Madison County), where there was the oldest and longest record for *Fagus*. *Tsuga* was not treated in this study, probably because of its extremely weak representation in the fossil pollen records of the area considered.

Analysis of Fossil Pollen Records

Recently Mrs. Darlene (Helmich) Southworth and I completed a re-analysis of Third Sister Lake sediments from Washtenaw County, Michigan particularly to determine the non-arboreal pollen. We confirmed the earlier analysis of these sediments (15) with respect to the late arrival and weak expression of *Fagus* and *Tsuga*. Those genera are similarly expressed in the diagram for Sodon Lake in Oakland County (2) about 40 miles to the northeast, except that *Fagus* arrived there earlier. These facts and the above-mentioned findings of Potzger and Friesner (13) led me to inquire into the records of *Fagus* and *Tsuga* in pollen diagrams from the Prairie Peninsula region in general. These two kinds of pollen grains provide suitable evidence because each represents only one species in this region, they are readily identified with certainty, and they are not likely to be overlooked or confused with other kinds.

From approximately 100 pollen diagrams from Ohio, Indiana, Michigan, and Illinois, 15 of the longest and most detailed records were selected as representative with respect to *Fagus* and *Tsuga*, one being a composite diagram of 5 bogs in north-central Ohio (Table 1, Figure 1). One diagram from Hancock County in north-central Iowa was included as an example of the record near the western margin of the Prairie. In each diagram the mean percentages (of total tree pollen) for *Fagus* and *Tsuga* were estimated for each of the vegetation sequence stages, which were expanded from the 5 post-glacial periods of Sears (20), as indicated in the heading of Table 1. Localities 3 to 15 in Table 1 are arranged in essentially a north-to-south order but with minor rearrangement to establish order in the times of appearance of the two genera. The Iowa record indicates the weak and brief appearance of *Fagus* in the Pine-Oak stage and the complete absence of *Tsuga* pollen in the post-glacial of the western part of the prairie. It must be kept in mind that the columns (stages of different predominant tree pollen) are not time units but stages in the succession of gross kinds of vegetation as indicated by fossil pollen. If time were indicated from left to right in Table 1, the columns successively to the left of Period III would be increasingly narrowed and displaced toward the right from the southernmost locality (15) to the northernmost (3). Therefore, Table 1 compares the appearance and relative dominance of *Fagus* and *Tsuga* pollen with the developmental stages of post-glacial vegetation in the selected localities. With increased numbers of radiocarbon dates and detailed pollen diagrams we can look forward to the day when it will be practicable to make these correlations on an absolute time scale.

TABLE 1. Occurrences of *Tsuga* (T) and *Fagus* (F) pollen in selected pollen diagrams from Late-glacial to near-modern time. Symbol "t" signifies presence generally less than 1% of total tree pollen; 1, 2, 3, etc. are approximate mean percentages during the vegetation stage indicated in heading. The total time span for the southernmost localities approaches 16,000 years, but for the northernmost is less than 11,000 years. At southern localities 10, 14, and 15, an extra vegetation stage of Pine-Oak-Hardwoods occurs between two Pine maxima and possibly represents the Two Creeks Interval as expressed in this region (Engelhardt, 1960; Frey, 1959).

Period (after Sears, 1942b) Vegetation stage (based on predominant tree pollen)	I Spruce-Fir	Pine-Spruce	II Pine	Pine-Oak	III Hdwds-Oak	IV Oak-Hickory	V Oak-Hdwds
1. Iowa, Hancock Co., Lane, 1931		---/ /--	----------	F1	---	--Steppe--	-----
2. Illinois, Lake Co., Voss, 1934						Tt	T2
3. Michigan, Cheboygan Co., Potzger, 1946	---/ /--	T1		Tt	T15 F4	T12 F10 Pine	T7 F7
4. Michigan, Clare Co., Potzger, 1948	Tt	Tt F1	T2 Ft	T2	T10 F10	T15 F3	T20 F12
5. Michigan, Berrien Co., Houdek, 1935	F1	F1	F1	F1	Tt F2	T3 F3	T2 F3
6. Michigan, Allegan Co., Potzger, 1948		F3	F1	T3 F10	T2 F20	T1 F15	T7 F10
7. Michigan, Oakland Co., Cain & Slater, 1948		F2	F1	Tt F1	Tt F3	T1 F3	-Tt F2
8. Michigan, Washtenaw Co., Potzger & Wilson, 1941		T1		F1	F2	Tt F2	T1 F8
9. Indiana, Steuben Co., Houdek, 1933		Tt Ft	F1	F1	F4	Tt F3	Tt F3
10. Indiana, Marshall Co., Frey, 1959		F1	Ft	Ft	F3	F2	F10
11. Indiana, Lagrange Co., Potzger, 1946				F1	Tt F11	Tt F5	F8
12. Indiana, Kosciusko Co., Potzger, 1946					F2	F3	Tt F6
13. Indiana, Adams Co., Potzger, 1946					Tt F10	T2 F5	F8
14. Indiana, Hamilton Co., Engelhardt, 1960			T1			F3	F4
15. Indiana, Marion Co., Engelhardt, 1960		Tt	F3 Tt Ft	T2 F1	F3	F4	F6
16. Ohio, N. Central, 5 bogs, Potter, 1947			T1 F1	T2 F10	T1 F40	Tt F2	F5

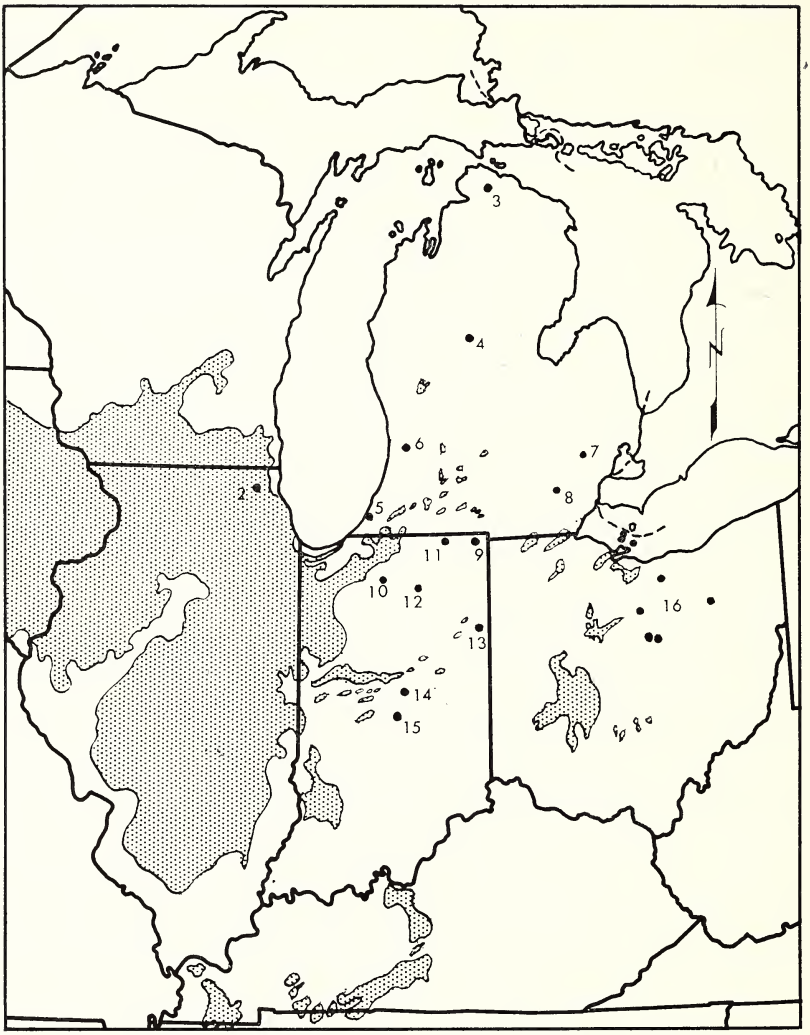

Figure 1. The Prairie Peninsula. Stippling represents areas containing concentrations of characteristic plant communities generalized and redrawn from detailed map by Transeau (23). Black dots mark localities of pollen diagrams 2 through 15, and five localities for composite diagram 16, all of which are listed in Table 1.

Discussion

We can be reasonably certain that both *Fagus* and *Tsuga* persisted in the southern Appalachians, probably even on parts of the Cumberland Plateau, during the Wisconsin glaciation of the area under discussion. *Tsuga* wood has been found in north-central Iowa and dated by radiocarbon in years B.P. as >17,000, 16,367±1000, 13,300±900, and

12,120±539 (16), although *Tsuga* does not appear in the post-glacial pollen record for Hancock County (Table 1, no. 1). By the Pine stage both *Fagus* and *Tsuga* were represented in the pollen record of Marion County, Indiana (locality 15) and north-central Ohio (localities in the area of 16). However, except for the brief appearance of *Tsuga* at locality 14 in the Pine stage, both genera failed to appear at localities 11 to 14 until the Pine-Oak stage or later. On the other hand, at localities 4 through 7 in Lower Michigan *Fagus* appeared not later than the Pine-Spruce stage. *Tsuga* appeared in the Spruce-Fir or Pine-Spruce stage at localities 4 and 3; *Fagus* appeared in the Pine-Spruce stage at 4, and in the Hardwoods-Oak stage at 3. It appears that *Tsuga* and *Fagus* began moving northward from their full-glacial refuges along with oaks and other hardwoods, following the retreat of spruce; but they were delayed in entering the northern half of Indiana and southeastern Michigan. The earlier appearance of *Tsuga* and *Fagus* in Steuben and Marshall Counties, Indiana (9, 10) than in surrounding localities is not understood. In general, it appears that the Prairie Peninsula served as a barrier to *Tsuga* and *Fagus* migration in early post-glacial time.

Another line of evidence in support of early post-ice invasion of grassland elements into the Prairie Peninsula region is to be found in the more recently described Late-glacial pollen spectra in which the non-arboreal pollen has been identified as far as possible. The early Spruce-Fir stage usually has a large component (20 to 100% based on total arboreal pollen) of non-arboreal pollen. For example, the spruce-dominated spectrum associated with woodland musk ox skeletal material in Kalamazoo County, Michigan, 13,000±600 B.P. in C^{14} years has a total NAP of 22.8% (1). Another spruce-dominated spectrum associated with a mastodon skull in Oakand County, Michigan, 11,900±350 B.P. in C^{14} years, has 85% NAP (22). The earliest organic sediments in Third Sister Lake (locality 8 in Figure 1 and Table 1), dominated by spruce pollen, also have more than 80% nonarboreal pollen (Benninghoff and Southworth, manuscript), but before pine dominance is attained in this diagram the total non-arboreal percentage drops to about 5%. This high proportion of non-arboreal percentage in the Late-glacial exceeds the proportion of non-arboreal pollen in many post-agricultural settlement spectra in this forest region. Common to both the Late-glacial and modern NAP maxima are *Ambrosia*, other Compositae, Cyperaceae, Gramineae, Chenopodiaceae-Amaranthaceae, and *Plantago*. *Artemisia* and Caryophyllaceae were more common in the Late-glacial spectra. These are evidences in support of earliest Late-glacial invasion by grassland elements, under conditions which, as Schmidt said (17), offered least resistance from competition. We must then reject Gleason's hypothesis that the grassland elements intruded between the northward retreating pines of the Pine stage and the invading hardwoods.

It is interesting that *Fagus*, and to some extent *Tsuga*, appear for the first time (localities 11 to 13) or attain strong positions (7, 8, 9, 10, and 14) just before or during the Oak-Hickory maximum. This appears to be evidence contrary to the concept of maximum warmth and dryness during the Oak-Hickory stage and contrary to the belief that the Prairie Peninsula either originated or expanded during this time, which is

usually taken to be about 3500 years ago. On the other hand, where *Fagus* and *Tsuga* were already well represented in the pollen diagram, they showed decreased dominance during the Oak-Hickory stage (and in some localities did not recover their previous status), evidence in support of the "Xerothermic" maximum. Obviously we need more evidence, and in greater variety, to indicate in more detail the nature of this fluctuation and associated climatic changes.

If we accept the premise that the Prairie Peninsula acted as a barrier to the northward migration of *Fagus* and *Tsuga*, then it remains to be explained how those genera reached the central, western, and northern parts of Lower Michigan, and the central and western parts before the attainment of Hardwoods-Oak dominance. The most logical solution is to postulate invasion from the east north of Lake Erie. This is the northern of the two migration routes postulated by Gleason (6, pp. 73-75), the other being a northward and westward route from the forests along the southern edge of the prairies. From comparisons of the records for localities 4 to 8 in Table 1, it appears that *Fagus* reached Berrien County (5) before it reached Clare County (4), Allegan County (6), and Oakland County (7). On the other hand, *Tsuga* appears in Clare County (4) well before it appears in any of the other three. There is no obvious explanation of these records; but they do suggest that *Fagus* and *Tsuga* entered Lower Michigan from the east and spread northwestward and westward, somehow bypassing Oakland County (7) at first and *Tsuga* spreading southward somewhat later than *Fagus*. These two forest trees occur in stands having the aspect of Hemlock—White Pine—Northern Hardwoods along the eastern shore of Lake Michigan almost to the extreme southwestern corner of Lower Michigan. Some stands of this kind in Allegan and Berrien Counties have reminded me very much of the "Transition Hardwoods" in Massachusetts, between the Oak-Mixed Hardwoods ("Central Hardwoods") and the Hemlock—White Pine—Northern Hardwoods to the south and north respectively. The Transition Hardwoods parallel in southwesternmost Lower Michigan is made the more impressive when one recalls the remarkable disjunct population of *Betula populifolia*, the gray birch, a prominent successional tree in the Transition Hardwoods of New England, formerly known from two very small areas in Lake County in the extreme northwest corner of Indiana (3). There is much to be investigated in connection with the post-glacial forest history of the southern shores of Lake Michigan.

If the Prairie Peninsula did exert a filter barrier effect on northward migration of tree species and did stall the direct northward migration of beech and hemlock from refugia south of the Ohio River, we have a plausible explanation of the absence of pollen spectra indicating Hemlock—White Pine—Northern Hardwoods between the Pine stage and the Hardwoods—Oak or Oak-Hickory stages in pollen diagrams from northern Indiana and southern Michigan. The Hemlock—White Pine—Northern Hardwoods in northern Lower Michigan and in the eastern Upper Peninsula must have formed from species that came from different source areas and that arrived at different times. This forest type probably originated in more or less its present range within this region,

rather than having migrated northward as a unit during post-glacial time.

It seems likely that the beech forests over northern Indiana and southeastern Michigan are not more than 5,000 or 6,000 years old, perhaps in places only about 3,000 years old. The markedly different characters of the beech forests and beech-maple forests of southern Indiana and southern Ohio, as compared with those of northern Indiana, northwestern Ohio, and southeastern Michigan, and these in turn with beech-maple forests of southwestern Michigan, are at least in part attributable to the effects of the Prairie Peninsula on post-glacial plant migration. We need more floristic phytosociological surveys of existing forest stands and detailed pollen analytical investigations at many more sites in this region to reconstruct properly the post-glacial history of this complicated phytogeographical region.

Summary

The Prairie Peninsula was identified by Gleason, and delineated and named by Transeau, on floristic evidence; it was subsequently shown by Schmidt, Smith, and others to have significance zoogeographically as well as phytogeographically. Gleason believed this feature developed eastward between the post-glacial Pine stage and the invasion of Hardwoods, and was intensified and extended by pre-settlement Indian fires; but Transeau ascribed its origin to a late post-glacial period of prolonged droughts.

A study of selected pollen diagrams from the Prairie Peninsula region demonstrates that *Fagus* (beech), although an early (Pine stage) migrant into central Indiana, failed to enter the Prairie Peninsula until 5,000 or 6,000 years ago, some time after this tree had migrated from an eastern source into the central and southwestern parts of Lower Michigan. *Tsuga* (hemlock) did not enter the Prairie Peninsula at any time during the post-glacial, and was slower than beech in migrating from an eastern source into central and southwestern Michigan. This evidence is interpreted to mean that the Prairie Peninsula is older than the Pine stage in central Indiana; and high percentages of grassland elements in the earliest Spruce-Fir stage in southern Michigan pollen diagrams is regarded as evidence that the Peninsula was established shortly after glacial retreat. At some localities within the Peninsula beech, and in a few instances hemlock, first appear in the pollen diagrams or attain strong positions just before or during the Oak-Hickory stage, which is usually accepted as the "Xerothermic interval"; obviously there is some inconsistency here.

It can be shown that the Hemlock—White Pine—Northern Hardwoods forest type of northern Michigan must have formed within its present range. Thus we can account for lack of evidence for this forest tpye between the Pine stage and Hardwoods stages in pollen diagrams from the Prairie Peninsula and somewhat farther south.

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CHEMISTRY

Chairman: KEITH WHITE, Hanover College,
QUENTIN PETERSEN, Wabash College, was elected chairman for 1964

ABSTRACTS

Some Reactions of Substituted Tetrahydrofuranones.[1] KEITH WHITE, RICHARD SCAMEHORN and ERLAND PORTER, Hanover College.—In the study of the asymmetric reduction of 2,5-dimethyl-2,5-diethyltetrahydro-3-furanone (I) and its oxime to the tetrahydro-3-furanol and the tetrahydrofuranyl amine, it was discovered that the cyclization of the furanone (I) was also stereospecific and that only one of the two possible racemates is obtained. It was postulated that only the least hindered form of I is stable enough to withstand the reaction conditions. As the first step in the determination of the configuration as either cis or trans diethyl, the ketone (I) was resolved by fractional crystallization from methanol and water of the brucine salt of the 4-carboxyphenyl-hydrozone. The conversion of the resolved ketone to methylethyl-diglycollic acid or to 2,5-dimethyl-2,5-diethyl-2,5-dihydrofuran without rearrangement is necessary to the proof of configuration. Routes to these compounds were reported.

Some Reactions of Benzoyl Isocyanate. JOHN W. MCFARLAND, JAMES B. HOWARD[1] and J. THOMAS PARSONS,[2] DePauw University.—When Grignard reagents were added to ether solutions of benzoyl isocyanate a variety of products was obtained depending upon the nature of the organometallic used. Ethylmagnesium bromide and benzoyl isocyanate gave N,N′-dibenzoylurea, benzoylurea, and benzamide. Both isopropyl and tert. butyl Grignard reagents produced N, N′-dibenzoylurea and a product resulting from two moles of isocyanate and one mole of Grignard reagent. Naphthylmagnesium bromide and benzoyl isocyanate afforded naphthamide and a product which appeared to result from the combination of three moles of isocyanate with one mole of organomagnesium compound.

Benzoyl isocyanate reacted rapidly with triphenylcarbinol even at 0°C. The main products from the reaction were N,N′-dibenzoylurea and a compound representing two moles of isocyanate and one mole of triphenylcarbinol. The amounts of the two products were dependent upon temperature and the ratio of the two reagents. High temperature or high isocyanate concentration favored N,N′-dibenzoylurea formation. At 0°C. only the 2:1 isocyanate:carbinol product was obtained. This latter compound reacted with benzoyl isocyanate to give N,N′-dibenzoylurea among other products.

1. This research was financed and supported by grants from Hanover College, the Research Corporation and the Petroleum Research Fund. The authors express their gratitude for this support.

2. Supported by an Undergraduate Research Participation grant from the National Science Foundation, summer, 1963.

The Use of Benzenesulfonyl Isocyanate as a Characterizing Reagent for Hindered Alcohols and Phenols. JOHN W. MCFARLAND and JAMES B. HOWARD,[3] DePauw University.—Benzenesulfonyl isocyanate reacted rapidly with sterically hindered alcohols and phenols to give crystalline derivatives. Whereas phenyl isocyanate and tert. butyl alcohol reacted extremely slowly at 100°C. in toluene at 0.01 molar concentration each, benzenesulfonyl isocyanate and tert. butyl alcohol reacted instantaneously and completely at the same concentrations in toluene at 0°C. Derivatives have been facilely prepared from such sterically hindered alcohols as tert. butyl alcohol, tert. amyl alcohol, triethylcarbinol, and diphenyl-carbinol. The phenols which have been characterized by their reactions with benzenesulfonyl isocyanate include 2,6-di-tert. butylphenol, 2,6-di-isopropylphenol, 2,6-dimethoxyphenol, 2,6-dimethylphenol, 2,4,6- trinitrophenol (picric acid), 2-phenylphenol, 2-ethoxyphenol, and 4-tert. butylphenol. All of the above derivatives were the expected urethanes. Triphenylcarbinol also reacted readily with benzenesulfonyl isocyanate at temperatures from 56°C. to 100°C. The chief product from this reaction, however, was N-(triphenylmethyl)benzenesulfonamide which apparently resulted from the decarboxylation of the normal addition product.

Hammett Acidity Functions of Some Organophosphorus Acids. A. GILBERT COOK, Valparaiso University.—The Hammett acidity functions of several organophosphorous acids at various concentrations have been determined in ethylene glycol solvent. They are compared with pK_a determinations as measures of relative acidities. The use of dimethyl sulfoxide as a medium for Hammett acidity function determinations is also discussed.

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3. Supported by an Undergraduate Research Participation grant from the National Science Foundation, summer, 1963.

Reductive Preparation of Oximes and the Selective Hydrolysis of their Acetates on Alumina[1]

Quentin R. Petersen

The reduction of the vinyl nitro compound, 6-nitrocholesteryl acetate (I) has been used since 1903 (1, 2) to prepare 6-ketocholestanol (III) and its acetate (II). More recent work (3, 4, 5) has improved the yield and ease of workup but the synthesis has remained essentially unchanged since that time, zinc and acetic acid remaining the reducing agent. The overall yield of the 6-keto compound (II) from cholesterol—the starting material for the synthesis of all cholestane derivatives—is about 86% following the most recent procedures.

In the course of our work on the synthesis of i-pseudocholesterol (6) we had need of applying this reduction to the analogous vinyl nitro compound, 4-nitro-pseudocholesteryl acetate (IV). Inasmuch as pseudocholesterol had, in general, shown the same reactions as cholesterol (6, 7, 8), it seemed reasonable that such a procedure would work. However, since the pseudocholesteryl acetate starting material was available in only five percent yield from cholesterol, the yields on nitration and reduction were of critical importance and the resulting thirty-one percent yield was not adequate for our synthetic purposes.

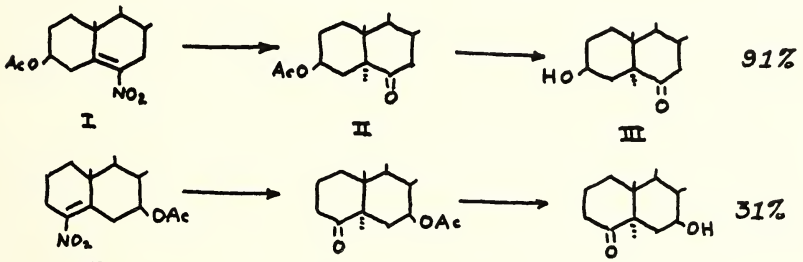

CHART 1

Consideration of the reaction path leading to the ketone suggests, as shown in chart 2, that it is a reduction of the nitro group to provide a vinyl amine (V) which suffers a proton shift to provide the imine (VI). Subsequent hydrolysis of the imine would provide the observed product. And, indeed, ammonia is produced as a reaction product (1, 2).

It seemed reasonable that the use of lithium aluminum hydride as a reducing agent instead of zinc and acetic acid might increase the yield of the ketone in the pseudocholesterol series if the vinyl amine (V) or

1. This work was performed at the University of Barcelona, Barcelona, Spain and at Wabash College. The author would like to acknowledge the hospitality shown him in the laboratory of Professor José Pascual Vila at the University of Barcelona and many helpful discussions with Drs. José Castells and Felix Serratosa of that laboratory. Special thanks are due to Dr. Juan Bastús who determined many of the solid-state infra red spectra.

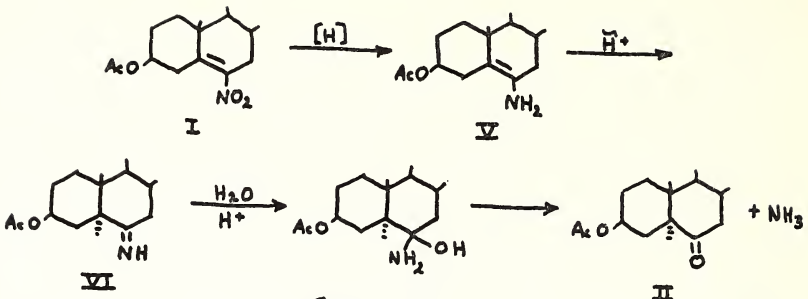

CHART 2

imine (VI) produced by the reduction of the nitro compound were removed from the reaction medium by salt formation with lithium in the fashion that other acidic groups form such salts. It would then be predicted that only upon the addition of water would further reaction of the vinyl amine (or imine) take place, and inasmuch as the water would destroy any remaining lithium aluminum hydride, the ketone produced would not be reduced further. It was, of course, expected that the acetoxy would also be reduced by the hydride. 6-Nitrocholesteryl acetate (I) was used as a model compound to study the reaction and its reduction with lithium aluminum hydride provided a good yield of a highly crystalline compound melting at 200° (VII), the elementary analysis of which showed the presence of nitrogen and the infrared spectrum of which showed free hydroxyl. Neither the percentages of nitrogen, carbon and hydrogen, nor the infrared spectrum suggested any specific substance, but clearly production of neither the ketol (III) nor its acetate (II) had obtained.

Acetylation of the compound provided, by chromatographic workup, a substance also melting at 200° (VIII) but showing both acetate and free hydroxyl in the infrared. When, however, workup was by crystallization alone a substance melting at 130° (IX), showing no free hydroxyl in the infrared was isolated as the sole product. In spite of almost identical melting points, the former acetate (VIII) was clearly distinct from the starting material (VII) and the latter acetate (IX) clearly distinct from the expected product 6-ketocholesteryl acetate (II). Both acetates provided, upon basic hydrolysis, the starting material (VII).

During the preparation of an analytical sample of the 130° acetate (IX) it was chromatographed on alumina and the sole product eluted proved to be the 200° acetate (VIII) in a very pure form. When this acetate was treated with acetic anhydride, the 130° acetate (IX) was resynthesized. Elemental analyses on these derivatives proved more meaningful and the identity of the reduction product was established as the oxime of 6-ketocholesterol (VII) and the derivatives as the mono (IX) and diacetates (XIII) of that substance, alumina chromatography having been capable of effecting hydrolysis of the oxime acetate selectively. The structures were verified by independent synthesis (9) from the known ketol (III) and its acetate (II) as shown on chart 3.

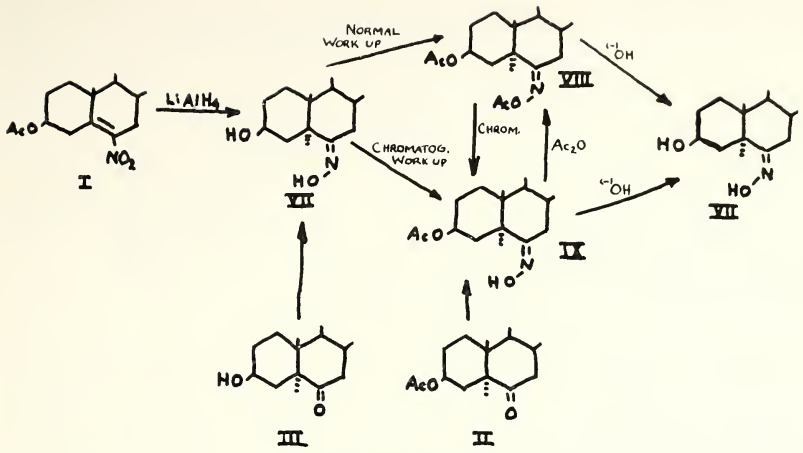

CHART 3

Thus, in contrast to the zinc and acetic acid reduction, the reduction with lithium aluminum hydride had stopped short of the vinyl amine (V) stage and, as shown in chart 4 might be considered to have proceeded through the vinyl nitroso compound (X) and the vinyl hydroxylamine (XI) at which point the reduction ceases with the hydroxyl group of (XI) presumably removed by salt formation. Hydrolysis of the salt and subsequent acid catalyzed rearrangement to the oxime would complete the reaction.

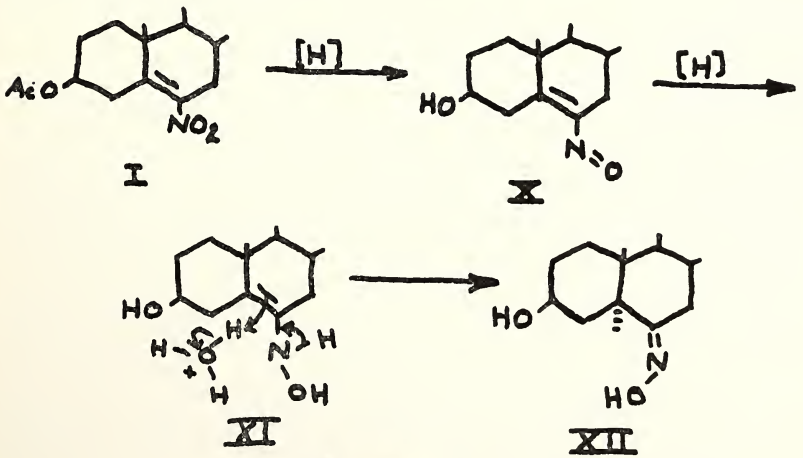

CHART 4

In order to generalize the behavior of the alcohol-oxime diacetate, 7-ketocholesterol oxime diacetate (XII) was sythesized and found to be converted essentially quantitatively to 7-ketocholesteryl acetate

oxime (XIII) upon passage over an alumina column in a fashion identical to the behavior of the 6-keto oxime diacetate (IX).

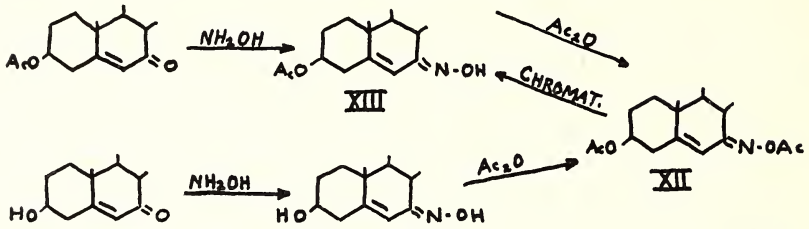

CHART 5

The infrared spectra of most of the compounds discussed were measured both in the solid state and in carbon tetrachloride solution. One unanticipated observation made on the spectra obtained by either technique was that when comparing pairs of compounds from the two series—that is, the saturated 3-hydroxy-6-oxime and the unsaturated 3-hydroxy-7-oxime—similarly substituted hydroxyl groups showed essentially identical adsorption frequencies. For example, the C=N stretching frequency (9, 10) at 1638 cm^{-1} in the saturated oxime diacetate (IX) is identical to that in the unsaturated system (XII). In view of the conjugation of the latter, this was certainly not anticipated.

The adsorption frequencies of the =N-OAc do not appear to have been reported and were found to differ significantly from those of the C-O-Ac but to resemble, not surprisingly, those of an enol ester (11), the carbonyl stretching frequency being elevated by 31 cm^{-1} in both series and the N-O-C band was 28 cm^{-1} lower than the C-O-C band in both series.

Experimental

6-Ketocholestanol oxime (VII)

To a slurry of 2.0 g. of lithium aluminum hydride in 200 ml. of ether was added over 30 min. a solution of 7.0 g. of 6-nitrocholesteryl acetate (I) in 50 ml. of ether. A vigorous reaction took place upon each addition of solution and toward the end of the addition a precipitate formed at the surface, dissolving as the initial reaction subsided. After addition was complete the mixture was heated for 10 min. and decomposed with 2 N sulfuric acid. After standing overnight the ether layer was filtered from a white precipitate (which possessed a definite ammonia odor) and evaporated to give 5.5 g. of a taffy-like solid which was crystallized from methanol to provide 4.0 g. of 6-ketocholestanol oxime, m.p. 180-190°. This material was recrystallized once from methanol to give needles, m.p. 206-208°, undepressed upon admixture with authentic 6-ketocholestanol oxime prepared from 6-ketocholestanol (4).

6-Ketocholestanol oxime diacetate (IX)

A solution of 0.7 g. of VII in 20 ml of acetic anhydride was refluxed for one hour, cooled to room temperature, and poured into 50 ml of cold water. After 20 hours the yellow, semicrystalline product was

removed and crystallized from acetone-water to a yellow granular solid. This solid recrystallized well from methanol to provide white needles, m.p. 130-131°. Anal. Calcd. for $C_{31}H_{51}O_4N$: C, 74.31; H, 10.24; N, 2.79. Found: C, 74.29; H, 10.34; N, 2.64. Treatment of VIII with acetic anhydride also provided this compound.

6-Ketocholestanol acetate oxime (VIII)

A solution of 0.2 g. of the diacetate IX in petroleum ether was passed over a 1 x 14 cm. column of alumina and then eluted with benzene. Evaporation of the benzene fractions provided 0.18 g of directly pure 6-ketocholestanol acetate oxime m.p. 202-204°. Recrystallization from acetone provided magnificent square plates of the same m.p., undepressed upon admixture with an authentic sample (12) prepared from 6-ketocholestanol acetate.

7-Ketocholesterol oxime diacetate (XII)

One tenth gram of 7-ketocholesterol oxime was dissolved in 10 ml. of acetic anhydride and refluxed for one hour. The resulting pale yellow solution was poured into water and after hydrolysis was complete a yellow mat of needles was filtered off. Two washes with cold methanol provided 0.09 g. of white needles m.p. 180-183°. Recrystallization from methanol gave 0.06 g. m.p. 183-186°. Anal. Calcd. for $C_{31}H_{49}O_4N$: C, 74.45; H, 9.87. Found: C, 74.39; H, 9.87.

7-Ketocholesteryl acetate oxime (XIII)

The diacetate XII, when treated with alumina in a fashion identical to that described for the diacetate IX provided 7-ketocholesteryl acetate oxime, m.p. 191-192, undepressed upon admixture of an authentic sample (13) prepared from 7-ketocholesteryl acetate.

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The Solubility of Magnesium Bromide in Di-n-Butyl Ether

JOHN A. RICKETTS and PAUL BROWN, DePauw University

Rowley (1) has extensively investigated the solubility of magnesium bromide in diethyl ether, Et_2O, and has found that magnesium bromide forms a solid mono-, di-, and tri-etherate with transition temperatures of 12° C. (tri-etherate to di-etherate) and 22.6° C. (di-etherate to mono-etherate). This investigation measures the solubility of magnesium bromide in di-n-butyl ether, Bu_2O, in the temperature range of 5° C. to 56° C. and also determines the chemical nature of the solid phase in equilibrium with the saturated solution of magnesium bromide in Bu_2O.

Experimental

Solubility measurements were taken at approximately 5° C. intervals. Any of the fixed temperature points that were used were controlled to $\pm$ 0.02°C. Excess solid was added to 50 ml. of pure Bu_2O contained in a 100 ml. round-bottomed flask. All Bu_2O used in the experiments was purified by fractional distillation from sodium on to sodium and only the fraction which distilled in the temperature range 141-2° C. was used. The refractive index of the Bu_2O was measured as 1.3990 at 20° C. (lit. 1.3992). The vapor phase chromatogram of the liquid contained only a single peak. The flask was mounted in the constant temperature bath and the closed system stirred mechanically for a period of time ranging from 4 to 12 hours. Samples of the liquid phase were withdrawn, weighed, and analyzed, one sample for magnesium ion using EDTA with Erichrome Black T as indicator and another sample from the same flask for bromide ion by the Vohlhard method. In withdrawing the liquid samples the tip of the pipet was covered with filter cloth so as to exclude any solid material; in addition the temperature of the pipet was slightly warmer than the temperature of the solution in order to prevent any precipitation of dissolved magnesium bromide during the transferring process. The validity of any determination was checked through the ratio of the weight of magnesium ion per gram of solution to the weight of bromide ion per gram of solution. The theoretical ratio is 0.1521; these ratios that deviated from the expected value by greater than three per cent were discarded.

Solubility measurements using anhydrous magnesium bromide (purity 99.9 per cent) as the initial solid phase gave irreproducible results even though the ratio of magnesium ion to bromide ion was acceptable. Suspecting that the stable solid phase was a di-n-butyl etherate of magnesium bromide, the solid starting material was synthesized as follows. Initially $MgBr_2.3Et_2O$ was prepared according the procedure described by Rowley (2). Excess c. p. magnesium turnings suspended in c. p. anhydrous Et_2O were reacted with chorine-free liquid bromine. The reaction was carried out under anhydrous conditions at the temperature of melting ice under a nitrogen atmosphere. The liquid layers were then separated from the excess magnesium. Solid $MgBr_2.3Et_2O$ separated

from the liquid when it was cooled with an ice-salt mixture. The solid tri-etherate was washed several times with Bu_2O and suspended in Bu_2O. Distillation of the mixture at a temperature below 75° C. removed all of the Et_2O. The solid phase was then washed with Bu_2O until the liquid layer remained water clear. Samples of the solid were freed from excess Bu_2O by suction filtration over an atmosphere of nitrogen, weighed, and analyzed for magnesium bromide. If the formula for the solid were $MgBr_2.Bu_2O$, the predicted percentage by weight of magnesium bromide is 58.48. Experimental percentages ranged between 53 and 60 per cent. Because the solid hydrolyzes rapidly in air and because the sample may not have been completely freed of physically adsorbed Bu_2O by the filtration process, the experimental results are thought to be precise enough to establish the formula for the solid phase as $MgBr_2.Bu_2O$. All the reported solubility measurements used the $MgBr_2.Bu_2O$ as the starting solid material.

Results and Discussion

Figure 1 summarizes the solubility data for magnesium bromide in Bu_2O. It has been constructed using data from three separate runs with

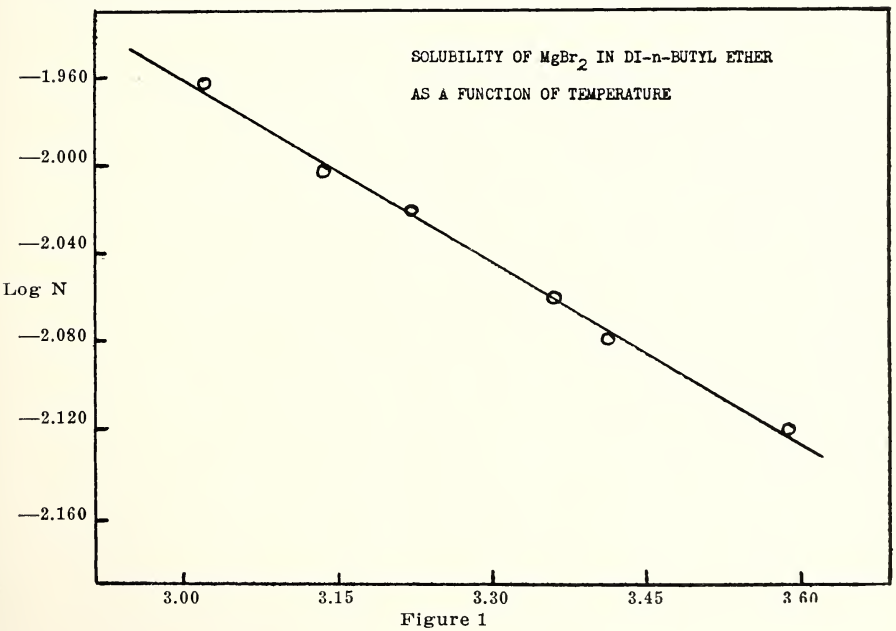

Figure 1

different preparations of $MgBr_2.Bu_2O$ as the solid phase. Treatment of the entire set of data, 22 separate determinations, by the method of least squares indicates that the equation which best represents the solubility of magnesium bromide in Bu_2O in the temperature range of 5.70° C. to 59.90° C. is

$$\log N = -\frac{283.7}{T} - 1.109 \qquad (1)$$

where N represents the solubility of magnesium bromide in terms of its mole fraction in the solution and T the absolute temperature. From equation 1 the differential heat of solution of $MgBr_2.Bu_2O$ in Bu_2O is calculated to be 1.30 ± 0.02 kcal. $mole^{-1}$. The curve, since no discontinuities occur, also indicates that in the temperature range studied the stable solid phase is $MgBr_2.Bu_2O$.

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A Complex of Cadmium (II) and Pyrocatechol Violet. Determination of the Molar Absorptivity and Dissociation Constant

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Pyrocatechol violet, 3,3′4′ -trihydroxyfuchsone -2″- sulfonic acid, forms colored complexes with many cations. The absorption of light by mixtures of this dye and various metal ions may readily be determined by spectrophotometric means. Such colorimetric data have been used for quantitative determinations of several metal ions (4, 5). Dissociation constants of complexes of eight cations with pyrocatechol violet have been determined (3). A complex of cadmium (II) and pyrocatechol violet has been reported (1); however, the complexity constant was not given. This study was undertaken to obtain the value of the constant and to determine the molar absorptivity of the complex.

Experimental

Stock solutions of cadmium chloride and pyrocatechol violet having concentrations of 0.000989 M and 0.001013 M, respectively, were prepared. Each compound was an analytical reagent grade chemical. For purposes of dilution, the stock solutions were added from 10-ml. burets to 100-ml. "red-line" volumetric flasks. As shown in Table 1, two series of solutions were prepared. Table 1a lists samples containing only

TABLE 1

1a			1b		
Concentration of P. V. ($\times 10^4$M)	Absorbance 420 mμ	620 mμ	Mole Fraction of P.V.	Absorbance 420 mμ	620 mμ
0.000	0.000	0.000	0.000	0.000	0.001
0.101	0.067	0.036	0.102	0.090	0.056
0.203	0.143	0.074	0.204	0.187	0.115
0.304	0.219	0.101	0.305	0.273	0.166
0.405	0.291	0.110	0.406	0.330	0.165
0.506	0.331	0.093	0.506	0.355	0.121
0.608	——	——	0.606	0.396	0.087
0.709	0.433	0.075	0.705	0.441	0.092
0.810	0.474	0.076	0.804	0.482	0.074
0.912	——	——	0.902	0.547	0.077
1.013	0.601	0.081	1.000	0.609	0.078

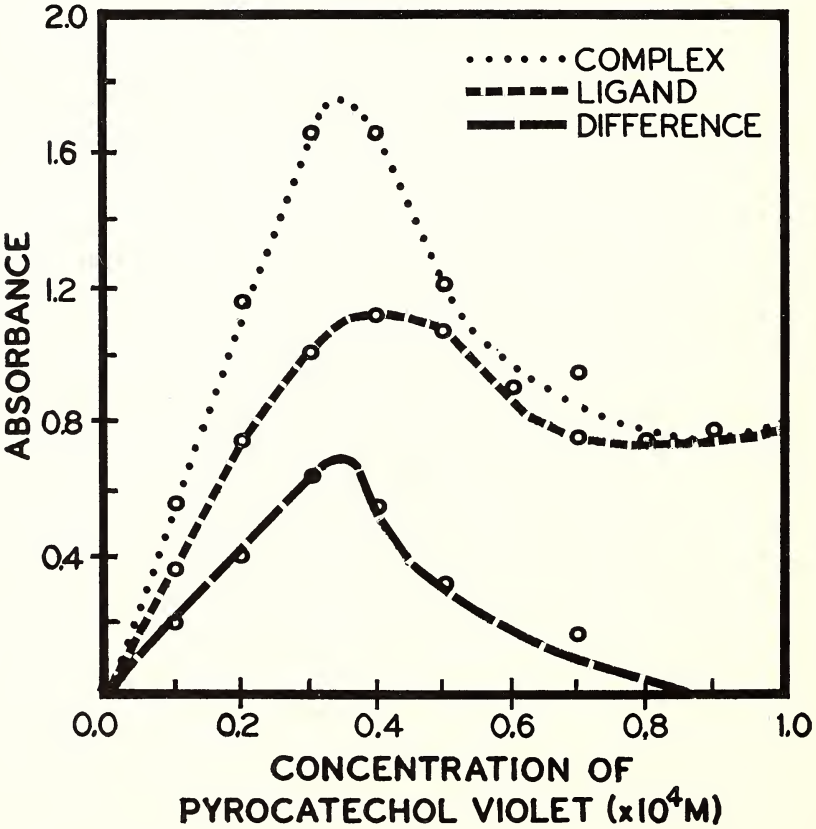
P.V. = Pyrocatechol violet

1. Acknowledgment is made of financial support received in part from a National Science Foundation Undergraduate Research Participation Program Grant at Saint Louis University.

pyrocatechol violet, while Table 1b lists samples containing mixtures of cadmium chloride and pyrocatechol violet. In the latter case, each solution was adjusted so that the total concentration of the salt plus the ligand equaled 0.001 M. The mole fraction of each mixture in terms of pyrocatechol violet is given in Table 1b.

A Bausch and Lomb Spectronic 505 recording spectrophotometer was used to determine the spectrum of pyrocatechol violet. The plot of absorbance showed a broad peak at 420 mμ and a broad trough at 620 mμ. The data listed in Table 1 were obtained with a Beckman Model DU quartz spectrophotometer equipped with 1-cm. cuvettes. The cuvette compartment was thermostated at 25.0 ± 0.1 °C.

The data showed deviations from Beer's law. The solutions changed colors upon dilution, going from a red-brown color at higher concentrations to a blue-green color at lower concentrations. The curve of pyrocatechol violet at 620 mμ is shown in Figure 1. The deviation from a



straight-line plot is quite large. Thus actual data for the absorbance were used in subsequent calculations rather than theoretical values as predicted by Beer's law.

The absorbance of pyrocatechol violet also varied somewhat with time. To minimize errors from this source, the same stock solutions were used to prepare solutions containing only the ligand and those containing the ligand plus the cation. Further, the dilute solutions were prepared at measured time intervals and absorbances were determined after identical time periods for each sample.

Calculations and Results

Job's method of continuous variations was applied to the spectrophotometric data (2, 6). The calculations were applied to the data at 620 mμ. At this wave length the difference in absorbance of the ligand and the complex was the greatest.

The dissociation of a complex ion may be written as

$$MA_n = M + nA$$

and the dissociation constant as

$$K = \frac{[M][A]^n}{[MA_n]} \quad (1)$$

If the total concentration of M plus A is m molar and the fraction of A present is x, then the added amount of A is mx moles/liter and that of M is m(1-x) moles/liter. At equilibrium between M,A, and MA_n

$$[M] = m(1\text{-}x) - [MA_n] \quad (2)$$

$$[A] = m(x) - n[MA_n] \quad (3)$$

Differentiating equation (1) gives

$$\frac{K}{[A]^n}\frac{d[MA_n]}{dx} = \frac{n[M]}{[A]}\frac{d[A]}{dx} + \frac{d[M]}{dx} \quad (4)$$

The concentration of the complex is a maximum when $\frac{d[MA_n]}{dx} = 0$.

Differentiating equations (2) and (3) and applying the test for the maximum gives

$$\frac{x}{(1-x)} = n \quad (5)$$

That is, the maximum concentration of the complex results when the concentrations of M and A are added in the same ratios as the formula of the most stable complex, MA_n. Similar derivations can be used to show that if a complex ion absorbs light, the maximum absorption occurs at the mole fraction indicated by the formula MA_n.

Figure 1 shows that the maximum absorbance occurred at a concentration of 0.0000333 M pyrocatechol violet and a concentration of 0.0000667 M cadmium ion, indicating a complex of type M_2A. Analysis of the data at 420 mμ resulted in the same formula, indicating the formation of only one stable complex. Further, only one maximum was found on each curve, another indication of the formation of but one stable complex.

The determination of the molar absorptivity and the dissociation constant was accomplished by applying a method of successive approximations to the spectrophotometric data. Let C_A = total concentration of ligand added, a_A = molar absorptivity of the pure ligand, a_C = the molar absorptivity of the complex, and A_t = the total absorbance of solutions containing mixtures of metal ion and ligand. The cadmium ion absorbed no light in the visible region, thus $a_M = 0$. Then

$$A_t = a_A(C_A - [M_2A]) + a_C[M_2A] \quad (6)$$

The successive approximations were applied to the data at 0.00001 M ligand and 0.0000333 M ligand. The molar absorptivity of the complex was assumed to remain constant with concentration, i.e., Beer's law was accepted as valid. The value of a_A depended upon concentration and had to be calculated separately for each of the concentrations chosen.

The method of successive approximations for determining K and a_C was applied by calculating the appropriate value for a_A and assuming some value for a_C. The assumed value, along with the absorbance data and the proper value for a_A, were substituted into equation (6). From this equation, an approximation for the $[M_2A]$ was determined. Then an approximate value for K was readily calculated. The approximate K permitted the determination of a better value for a_C, and the process was repeated alternately at the two chosen concentrations until no change was noted in the dissociation constant or the molar absorptivity of the complex. The final values were $K = 1.44 \times 10^{-10}$ and $a_C = 5813$.

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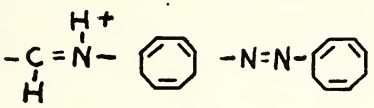
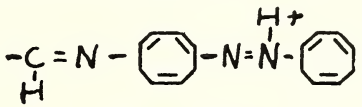
The Addition of Protons to Schiff Bases of p-Phenylazoaniline. Tautomeric Equilibrium Between the Azonium and Ammonium Species

JOHN A. RICKETTS and CATHERINE PIERSON,[1] DePauw University

Schiff base derivatives of p-phenylazoaniline form both a monoprotonated and a diprotonated species in acid solution (1). Since the base species, the monoprotonated species, and the diprotonated species absorb electromagnetic radiation of different wave lengths, the equilibrium constants that are associated with proton addition can be studied spectrophotometrically. In particular the addition of the first proton to the neutral base results in a tautomeric equilibrium between the species



Ammonium Form



Azonium Form

Consider the addition of a proton to a base species, B, which results in a mixture of monoprotonated acids, BH_1^+ and BH_2^+. If C is the stoichiometric concentration of the base plus the two acid species, and a_1 and a_2 represent the fractions of the base converted to $B+H_1$ and BH_2^+ respectively, then two separate acid dissociation constants exist,

$$K(1) = \frac{(1 - a_1 - a_2) \times a_{H_3O^+}}{a_1 \times f_{\pm}} \qquad (1)$$

and

$$K(2) = \frac{(1 - a_1 - a_2) \times a_{H_3O^+}}{a_2 \times f_{\pm}} \qquad (2)$$

where $a_{H_3O^+}$ refers to the activity of the hydronium ion in the solution and $f_{\pm}$ to the mean activity coefficient in the solution. The activity of the solvent has been assumed to be unity. Experimentally it is the total fraction of base converted to a protonated species that is measured and the equilibrium constant,

$$K = \frac{(1 - a_1 - a_2) \times a_{H_3O^+}}{(a_1 + a_2) \times f_{\pm}} \qquad (3)$$

is determined. K is related to K(1) and K(2) by the equation,

$$\frac{1}{K} = \frac{1}{K(1)} + \frac{1}{K(2)} \qquad (4)$$

The tautomeric equilibrium constant, K(T), is simply

$$K(T) = \frac{K(1)}{K(2)} \qquad (5)$$

If K(T) is a true tautomeric equilibrium constant, it is independent of the acid concentration of the solution.

1. This project was done as part of an Undergraduate Research Participation Program supported by the National Science Foundation at DePauw University during the summer of 1963.

At a wave length at which B absorbs and BH_1^+ and BH_2^+ are relatively transparent, equation 3 becomes

$$pK = pH + \log \frac{(D - D_B)}{(D_{BH} - D)} + \log f_{\pm} \quad (6)$$

D is the absorbance of the system at the pH of the solution, D_B is the absorbance at a pH at which only the base species is present, and D_{BH}^+ is the absorbance at the pH at which no base species is present. Since it is impossible to measure the molar absorbance of either BH_1^+ or BH_2^+ directly, it is necessary to determine K(T) by an alternate method.

The following deduction is based upon the assumption that at the wave length of maximum absorption of either acid species, the other acid species is transparent. At any pH at which B, BH_1^+, and BH_2^+ are present, at the wave length of maximum absorption of BH_1^+

$$D - (1 - a_1 - a_2)\, D_B = a_1\, D_{BH_1}^+ \quad (7)$$

D is the experimental absorbance of the solution at the particular wave length, D_B is the absorbance of the system if it were entirely in the base form at this particular wave length, and $D_{BH_1}^+$ represents the absorbance of the system at this wave length if the entire concentration of the dye molecule was present as BH_1^+. At the wave length of maximum absorption of BH_2^+ at the same pH

$$D' - (1 - a_1 - a_2)\, D'_B = a_2\, D'_{BH_2}^+ \quad (8)$$

The prime denotes that a different wave length is involved. Using the value of K, the sum, $a_1 + a_2$, can be calculated at any given pH value. At that pH at which none of the base species is present—experimentally determined as that acid strength where the system displays its minimum absorbance at the wave length of maximum absorption by the base species—the relationships are

$$D_{max} = a_{1max} D_{BH_1}^+ \quad (9)$$

and

$$D'_{max} = a_{2max} D_{BH_2}^+ \quad (10)$$

with the sum, $a_{1max} + a_{2max}$, equal to unity. These equations can be solved for a_1 and a_2 at any acid strength and K(T) determined.

If the monoprotonated acid species can add a second proton to form the diprotonated BH_2^+, the effective second acid dissociation constant is

$$pK' = pH + \log \frac{(D - D_{BH}^+)}{(D_{HB2}^{++} - D)} \quad (11)$$

D is the absorbance of the solution at the wave length at which BH_2^+ absorbs, $D_{BH_2}^{++}$ is the absorbance when only the diprotonated species is present, and D_{BH}^+ is the absorbance when only the tautomeric monoprotonated forms are present.

Experimental

The Schiff bases N-benzal-p-phenylazoaniline, N-(p-chlorobenzal)-p-phenylazoaniline, and N-(p-methoxybenzal)-p-phenylazoaniline were prepared by the method of Guilhot (2). The appropriate aldehyde was reacted with a concentrated solution of p-phenylazoaniline in absolute ethanol at the temperature of melting ice. The Schiff bases, which precipitated, were then recrystallized three times from ethanol and vacuum dried. Stock solutions of the bases were made up in absolute ethanol.

The spectrum of each base was determined in a solution of pH 5, in 1 molar HCl, and in 96 per cent H_2SO_4 solution in the range of 220 to 700 mu with a Bausch and Lomb Spectronic 505 recording spectrophotometer. These initial spectra presented the spectral characteristics of the base, the monoprotonated, and the diprotonated molecule. The effect of pH on the absorption characteristics of each Schiff base was studied using a Beckman DU Spectrophotometer. Matched silica cells were employed, and the cell compartment was thermostated to 25.0 ± 0.2°C. The range of acidities covered was from a pH 7 through concentrated H_2SO_4. In the pH range 1 through 7, buffer solutions of ionic strength 0.1 were employed; the pH of each buffer was determined with a Beckman Model G pH meter. The pH values of the various H_2SO_4 solutions were estimated using the extended pH scale of Michaelis and Granick (3). At each pH 2 ml. of stock ethanolic Schiff base was diluted to 25 ml. with the appropriate solution and the absorbance was measured at three wave lengths about each maximum. In order to determine the absorbance of the solution when only the monoprotonated species was present, the absorbance of the solution was taken at the wave length of maximum absorption of the base species in dilute H_2SO_4 solutions until the absorbance at this wave length reached its minimum value. The concentration of H_2SO_4 at which the minimum absorbance was found varied between 1.5 and 3.1 normal, depending upon the particular base.

Results and Discussion

Table 1 summarizes the spectral characteristics of the Schiff bases as well as listing the first and second acid dissociation constants for the protonated species. Data for p-dimethylaminoazobenzene has also been included, since tautomeric equilibria in the case of the monoprotonated Schiff bases is best explained by their similar spectral behavior to this molecule.

In the case of substituted p-dimethylaminoazobenzenes the existence of tautomeric equilibrium between monoprotonated cationic species has been postulated by many, notably Badger (4), Sawicki (5), and Jaffe (6). These workers assign the absorption band at 320 mu to the ammonium species and the absorption band at 515 mu to the azonium form. This assignment is based upon a spectral comparison with substituted azobenzene molecules and their monoprotonated forms. The most conclusive evidence is afforded by Jaffe (7), who studied the addition of protons to p-dimethylaminoazobenzene and to the monomethyl sulfate salt of p-trimethylammoniumazobenzene. In 5 per cent H_2SO_4 the ammonium salt had only one absorption band with a maximum at 320 mu while p-dimethylaminoazobenzene has two separate bands at 320 mu and 515 mu. In stronger H_2SO_4 solutions the ammonium salt absorbs at 408 mu, its monoprotonated species, while the dimethylaminoazobenzene absorbs at 415 mu, its diprotonated species.

The spectral behavior of the Schiff bases in acid solution is similar to p-dimethylaminoazobenzene. The most striking difference is a twin peak associated with the diprotonated Schiff base. This absorption band seems due to the a single diprotonated species since the second acid dissociation constant had the same value regardless of which absorption

TABLE 1

Spectral Characteristics and Acid Dissociation Constants of the Schiff Bases of p-Phenylazoaniline

Compound	Wave length mu.	Molar Absorbance x 10^{-3}	pK	pK'
N-Benzal-p-phenyl-azoaniline			2.75± .02	—3.39± .05
Base	375	20.3		
Monoprotonated	320	21.2		
	495	54.8		
Diprotonated	295	25.4		
	415	32.0		
N-(p-Methoxybenzal)-p-phenylazoaniline			2.83± .03	—3.84± .02
Base	375	20.1		
Monoprotonated	290	25.9		
	495	45.6		
Diprotonated	350	42.3		
	415	29.2		
N-(p-Chlorobenzal)-p-phenylazoaniline			2.74± .02	—3.85± .03
Base	375	19.7		
Monoprotonated	320	23.0		
	495	41.7		
Diprotonated	320	28.8		
	415	30.6		
p-Dimethylamino-azobenzene			3.16± .03	—4.56± .01
Base	415	20.0		
Monoprotonated	320	22.6		
	515	64.2		
Diprotonated	415	35.0		

maximum was used. It was observed that in those H_2SO_4 solutions in which the diprotonated form began to appear that the absorbance associated with the ammonium species decreases and simultaneously the absorbance of the azonium species increases. This experimental evidence indicates definitely that the two monoprotonated species are different. If a tautomeric equilibrium does exist between monoprotonated Schiff bases, another effect besides the simple addition of a second proton to the acid cations must be occurring.

Table 2 summarizes the tautomeric equilibrium constants associated with monoprotonation as calculated using equations 7-10. The constancy of these values indicates that a tautomeric equilibrium does exist. In the case of the Schiff bases the relative order of magnitude of K(T) is that expected. The chloro group would inductively decrease the electron

TABLE 2

Tautomeric Equilibrium Constants for the Monoprotonated Species

Compound	pH	K(T) = Azonium / Ammonium
N-Benzal-p-phenyl azoaniline	2.45	0.198
	2.15	0.201
	1.74	0.209
	1.23	0.205
N-(p-Methoxybenzal)-p-phenylazoaniline	2.45	0.0180
	2.15	0.0189
	1.74	0.0195
	1.23	0.0198
N-(p-Chlorobenzal)-p-phenylazoaniline	2.45	0.265
	2.15	0.381
	1.74	0.295
	1.23	0.286
p-Dimethylaminoazobenzene	2.45	1.28
	2.15	1.28
	1.74	1.31
	1.23	1.29

density at the azomethine nitrogen while the methoxy group should enhance the electron density at the azomethine nitrogen through a resonance effect. The value of 1.3 for K(T) in the case of p-dimethylaminoazobenzene is especially interesting since Yeh (8) by assuming that the molar extinction coefficients for the monomethyl sulfate salt of p-trimethylammoniumazo benzene and the ammonium form of the monoprotonated p-dimethylaminoazobenzene were identical, determined K(T) to be 1.4 in 6.6 per cent H_2SO_4.

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ENTOMOLOGY

Chairman: B. E. Montgomery, Purdue
Gertrude Ward, Earlham College, was elected chairman for 1964

ABSTRACTS

Population Build-up of *Oulema melanopa (L.)* in Indiana and the Apparent Influence of Wind on Dispersion. Richard E. Shade and M. Curtis Wilson, Purdue University.—A survey was made to ascertain the extent of build-up of the cereal leaf beetle, *Oulema melanopa* (L.), over a one-year period since it was first identified from Indiana. The 1963 survey duplicated the technique used by the office of the State Entomologist in 1962 and was confined to the same area. It was made both years during a period of five days in the middle of August, at which time counts were low because most of the population was aestivating. However, results of the 1963 survey show a ten-fold increase in the number of beetles collected. In contrast to 1962 when only 12.5% of the samples contained beetles, 44% of the collections showed infestation in 1963. In 1962, all beetles collected in this survey were found in an area extending 8 to 11 miles from south south east to east south east of Galien, Michigan, the center of the infestation. In 1963, they were collected 10 miles southwest of Galien, east south east for 23 miles and directly south to the limit of the survey area, which was ten miles.

Using daily prevailing wind direction, a graphic illustration (wind rose) was made for the area during the period of May 1 to June 30, 1963 when the beetles are most active. It was then plotted on a map of the infested three state area along with the known peripheral points of infestation. The close approximation of the wind rose with the infested area suggests that the prevailing winds are a major factor in the dispersion of this insect.

Known Occurrence of Cereal Leaf Beetle, *Oulema melanopa*, in Indiana, 1963. James A. Clark, Indiana Department of Conservation.—Survey for cereal leaf beetle during the summer of 1963 revealed parts of twenty-five counties to be infested. This is an increase of twenty-three counties over the 1962 survey. State quarantine has been altered to cover the known infested areas.

Occurrence of *Wyeomyia smithii* (Coquillett) in Indiana. R. E. Siverly, Ball State College.—Larvae and pupae of *Wyeomyia smithii* (Coquillett) were collected in Pinhook Bog in La Porte County, Indiana, in August, 1963. Immature specimens of this mosquito were taken from water contained in the leaves of the pitcher plant, *Sarracenia purpurea*. *W. smithii* usually is found wherever this pitcher plant occurs, but the immature stages are found in no other micro-habitat. The occurrence of *W. smithii* has been reported from neighboring states. To the author's

knowledge, there are no previously published accounts of the occurrence of this mosquito in Indiana. Apparently little is known concerning the biology of this mosquito. It is not known to bite man and would appear to be of minor economic importance as a pest or vector mosquito.

Further studies of the composition of some Indiana nectars. B. ELWOOD MONTGOMERY, Purdue University.—This paper is a continuation of the preliminary studies reported in 1958. It includes the results of the analysis of the sugar content of samples of nectar obtained from flower-visiting bees during the past three seasons. Correlations and relationships of the sugar content of nectar with relative humidity, temperature and season of flowering are shown.

Drosophila **control on canning tomatoes.** GEORGE E. GOULD, Purdue University.—Eggs of the fruit fly, *Drosophila melanogaster* Meigen, are considered a contaminant by Federal officials when found in processed tomato products. Large populations of this fly appear in tomato fields in late August and September and lay eggs in cracks of the fruits. Field applications and hamper treatments with insecticides have been partially successful in reducing the number of eggs. In recent experiments two organophosphate insecticides, dichlorvos and Guthion, have given promising results.

The relative attractiveness of electric lamps to nocturnal insects. RALPH A. KILLOUGH, USDA, Beltsville, Maryland, and HOWARD O. DEAY, Purdue University.—Experiments were conducted during the summers of 1958 and 1959 at Lafayette, Indiana to determine the attractiveness of various commercially available lamps to nocturnal insects out-of-doors. Fourteen kinds of 15-watt fluorescent lamps (colors ranging from red through blacklight BLB, including several whites), ten kinds of 150-watt incandescent lamps (from red through a clear bulb), a 100-watt mercury-vapor lamp, and seven kinds of neon or argon "type" tubes (18 inches long) were compared. It was found that for insects in general the attractiveness of the lamps was as follows: BL fluorescent>BLB fluorescent and mercury-vapor>inside-frosted, white, and clear incandescent >remaining lamps (except the yellow and the red)>the yellow and the red lamps.

Insects and Other Arthropods of Economic Importance in Indiana in 1963

JOHN V. OSMUN, Purdue University[1]

Because of the importance of bioclimatology as an influencing factor in insect development, this annual report commences with a review of the pertinent weather occurrences during the year. The 1963 growing season followed one of the most severe winters on record in Indiana. The spring and summer months were characterized by unusual conditions of fluxuation and drought. April commenced rather normally with respect to temperature and rainfall, although the latter was down in the southern part of the state. May was extremely hot in the early period, but temperatures then dropped to below freezing late in the month with record lows in the southeastern area. June was warm changing to cold and then hot late in the period. July was characterized by prolonged dry hot periods, but August was relatively cool and below normal. September and early October were unseasonably warm. The most striking occurrence of the weather was the dry period extending from the second week in June through early October. During this period northern Indiana was 3.9 inches below normal in rainfall, central Indiana 5.9 inches, and southern Indiana 3.7 inches. September is reported as the driest since 1897. It is impossible to generalize on the effect of this season as related to insect development. Many species reacted noticeably to the conditions as will be indicated below. It is suspected that many insects will go into the winter with certain nutritional deficiencies which may influence activity next spring.

Field and Crop Insects

Armyworm (*Pseudaletia unipuncta* (Haw.)) infestations were considerably more abundant than they have been for several years. Some small grain fields were nearly stripped in LaPorte and St. Joseph counties. Growers initiated control measures on a large scale and serious loss was prevented; control measures were instituted on an estimated 35,000 acres.

A billbug (*Sphenophorus callosus* (Olivier)) was less destructive in Montgomery County where it has been a problem in fields with a muck soil. Drainage of the land, the control of the weed host, nutgrass (*Cyperus esculentus* L.), and the use of insecticides have greatly reduced the population. In Decatur County a second species of billbug (*S. zeae* Walsh) caused slight injury to small corn in two fields that had sod in them the previous year.

Blister beetles (*Epicauta spp.*) were of no economic importance in 1963.

The cereal leaf beetle (*Oulema melanopa* (L.)) received more attention than any other insect in Indiana during 1963. This was in line

1. Information for this summary has been provided by: W. L. Butts, H. O. Deay, R. C. Dobson, R. E. Dolphin, R. T. Everly, R. L. Gallum, R. L. Giese, G. E. Gould, D. W. Hamilton (USDA), D. L. Schuder, M. C. Wilson.

with its position of being new and of being the first known pest introduced directly into the Midwest from the Old World. It is a serious threat to grains and forage grasses. It was found in 25 counties in northern Indiana. However, severe infestations occurred only in townships along the Michigan State border in St. Joseph and LaPorte counties. Three fields of oats are known to have been plowed under because of complete loss. Damage is expected to be more severe in 1964 as beetle populations develop. Purdue, Michigan State, and Ohio State Universities and the USDA are cooperating in a diversified research effort. New facilities for this project include a mobile field laboratory and a programmed comparative ethology chamber. Areas of investigation for control of this species include biology, ecology, behavior, host plant resistance, and control with parasites, predators, and pathogens, attractants, and chemicals.

Common stalk borer (*Papaipema nebris* (Guen.)) was not particularly important, although it was observed damaging rye and wheat in St. Joseph County.

Corn earworm (*Heliothis zea* (Boddie)) populations were the lowest in six years. Light trap catches showed that the flight normally expected in the last half of August did not materialize. There was a small flight on September 19, and sweet corn silking at that time was severely damaged especially in the south. There were no infestations of importance in tomatoes. The fall insect survey showed southern corn to be damaged as follows: 3.4 per cent of plants infested, 9.3 kernels destroyed per infested ear, and 24.6 per cent of the fields showed some infestation.

Corn leaf aphid (*Rhopalosiphum maidia* (Fitch)) has increased greatly in the southern half of the state, particularly in mid-season and late-planted corn. An average of 58.7 per cent of plants were infested and 88.8 per cent of fields examined showed infested plants. Many small ears were found in heavily infested fields with the tip of the ear pollinated, but without developed seed. The per cent of plants infested broke down to: 6.2 per cent severely infested with nubbin ears or barren, 21.5 per cent heavily infested with incompletely developed ears, and 31.0 per cent lightly infested with ears about normal although smaller than on non-infested plants.

Chinch bug (*Blissus leucopterus* (Say)) populations remained at non-economic levels.

European corn borer (*Ostrinia nubilalis* (Hbn.)) infestation was slightly higher in 1963 in the state averaging 35.7 borers per 100 plants as compared with 28.9 in 1962. The heaviest infested area was the north-northwest area with 72.5 borers per 100 plants, slightly lower than the previous year. The greatest increase in populations occurred in the north-northeast, south-southwest, and south-southeast areas. Increases ranging from 125 to 500 per cent. All fields in the northern half of the state had some infestation, with the heaviest field in the entire state occurring in the north-northeast with 76 per cent plants infested, 304 borers per 100 plants and an estimated loss in yield of 9 per cent. Approximately 76 per cent of the fields in the southern half of the state were infested. The loss in yield in 1963 was estimated at 1.1 per cent or 4,318,400 bushels of corn compared with 0.8 per cent loss in 1962. Heavy

infestations in potatoes again occurred in Jasper County. This suggests the possibility that early planted potatoes are more attractive to the first generation moths and may provide higher survival than early planted corn in this area. This condition exists on the east shore of Virginia.

The southern corn rootworm (*Diabrotica undecimpunctata howardi* (Barber)) was present in normal numbers in corn fields. Its abundance on cucurbit crops was somewhat lower than usual.

Northern corn rootworm (*Diabrotica longicornis* (Say)) was widespread and damaging this past year. Reports were received from many parts of the state, especially relating to the beetles feeding on the silks of corn during August. An area of heavy infestation occurs in the northern section of the state. In Henry County, yield losses in one field are estimated at 30 per cent. To date, no resistance to chlorinated hydrocarbons has been reported or observed in Indiana.

The striped cucumber beetle (*Acalymma vittata* (Fab.)) occurred at levels similar to those in 1962.

Fall armyworm (*Laphygma frugipenda* (J. E. Smith)) was not important even in the pocket area frequently infested in previous years.

The fruit fly (*Drosophila melanogaster* (Meig.)) continued to be a major problem in tomato fields, although in general growers thought the population down from that of 1962.

Grasshopper (*Melanoplus spp.*) populations showed no increase over 1962. Damaging infestations occurred in localized areas in central, western, and southern areas of the state. Crops infested included soybeans, tomatoes, tobacco, and home gardens. *M. differentialis* (Thomas) and *M. femurrubrum* (DeG.) were again the dominant species.

Hessian fly (*Phytophaga destructor* (Say)) field populations of Race B, capable of infesting wheat varieties Dual, Monon, Redcoat and Reed have increased in size and virulence. Samples from 180 certified wheat fields showed an increase over 1962 of W38 resistant wheats becoming infested by this species. No infested samples were collected from Knox 62, a wheat having a different source of resistance from W38, which indicates this latter variety is maintaining resistance against Race B populations of *P. destructor.*

The tomato and tobacco hornworms (*Protoparce quinquemaculata* (Haworth) and *P. sexta* (Johan.)) were conspicuous this year by their absence. A few were observed in late July, but not enough to cause serious injury.

The Japanese beetle (*Popillia japonica* (Newman)) was present again in Newton County in destructive numbers. Populations on soybean foliage were slightly less than in 1962, but the area of heavy infestations enlarged during the past year. Damage was noted in several fields seven miles north of the area around the junction of roads 24 and 71.

Meadow spittlebug (*Philaenus spumaria* (L.)) infestations were less severe on alfalfa and clover than the two previous seasons.

Potato leafhopper (*Empoasca fabae* Harris) continued in general abundance across the state. Plant damage was more severe than the two previous years because of below-normal rainfall.

The spotted alfalfa aphid (*Therioaphis maculata* (Buckton)) was collected for the first time in early spring in Indiana near Maukport in Harrison County. This suggests that it may have overwintered. It did not, however, increase to any significant number.

The cabbage looper (*Trichoplusia ni* (Hubner)) and the imported cabbage worm (*Pieris rapae* (L.)) were severe in late cabbage in most areas of the state.

Wireworms (*Melanotus* spp.) damaged field corn in extensive areas of the state. Reports of losses in Decatur County were common.

Angoumois grain moth (*Sitotroga cerealella* (Oliver)) was less of a field problem this year with only 2 per cent of the fields infested in Gibson, Warrick, and Spencer Counties. Actual loss from this insect decreased one-third over the previous year. Everly's data show that the actual occurrence in the field increased five fold from September 15 to November.

Fruit Insects

European red mite (*Panonychus ulmi* (Koch)) continued to be the most prevalent species attacking fruit. Although early season activity was retarded because of the low spring temperatures, heavy populations developed by mid-season. Difficulties were experienced in maintaining control since the species has developed resistance to most of the acaricides labelled for use on fruit.

Two-spotted spider mite (*Tetranychus telarius* (L.)) was abundant in apple orchards, especially in the southern half of Indiana. Populations were not as heavy as those experienced from 1960 through 1962 because of the cool wet spring. This species is resistant to most of the labelled miticides.

Four-spotted spider mite (*Tetranychus canadensis* (McGregor)) was not numerous in Indiana orchards. Heaviest populations were observed in western Illinois orchards.

Red-banded leaf roller (*Argyrotaenia velutinana* (Walker)) populations were low and readily contained by recommended spray schedules.

Aphids—There were no serious outbreaks of the rosy apple aphid (*Anuraphis rosea* Baker) or the apple aphid (*Aphis pomi* De Geer). Limited outbreaks of aerial colonies of the woolly apple aphid (*Erisoma lanigerum* (Hausmann)) were present.

Codling moth (*Carpocapsa pomonella* (L.)) populations and injury were extremely light, partly because of the cold spring temperatures that retarded first-generation activity, but also because of the outstanding insecticides used to prevent injury, especially Guthion and carbaryl. Need for a well-planned insecticide program to control this pest was demonstrated by collection of 10,000 overwintering larvae from corrugated paper bands placed around unscraped tree trunks of 150 apple trees in an orchard where control was attempted by using a light dust program.

Plum curculio (*Conotrachelus nenuphar* (Herbst)) produced lighter than average injury on apples, even on unsprayed trees. Overwintering

adult populations seem to have been reduced by the extreme low temperatures encountered in January.

Forbes scale (*Aspidiotus forbesi* Johnson) and San Jose scale (*Aspidiotus perniciosus* Comstock). Infestations continue to be light in most orchards, but a heavy infestation of San Jose scale in a small isolated orchard near Vincennes has not been readily controlled the past two seasons with the control measures generally recommended. Reasons for increase in this orchard are not apparent.

Leaf miners—No major outbreaks of apple or peach leaf miners were observed in 1963.

Apple maggot (*Rhagoletis pomonella* (Walsh)) populations were similar to those of the past few seasons.

Periodical cicada, Brood 23, with a 13 year life cycle emerged in 1963. The major portion of adults was comprised of individuals of the two species *Magicicada tredecim* (Walsh and Riley) and *M. tredecassini* Alexander and Moore; however, a small number of individuals from the species, *M. tredecula* Alexander and Moore, also comprise a portion of the whole population for the brood. A partial survey of apple and peach orchards where emergence occurred in 14 orchards in Indiana in 4 counties, Sullivan, Knox, Gibson, and Vanderburg, showed that they occurred in 400 acres of apples and 225 acres of peaches. Brood 3, with a 17 year life cycle, also emerged in small numbers in 3 counties, Pulaski, McDonough and Fulton.

A thrips (*Frankliniella tritici* (Fitch)) was active and caused "dimpling" of apples during the bloom period.

The complete crop failure for peaches prevented observations on many of the peach insects normally reported.

Oriental fruit moth (*Grapholitha molesta* (Busck)) injury to terminal twigs was heavier than usual in numerous orchards since no insecticides were applied to the trees. Heavy overwintering populations are anticipated.

Peach tree borer (*Sanninoidea exitiosa* (Say)) was relatively unimportant.

Lesser peach tree borer (*Synanthedon pictipes* (Grote & Robinson)) caused moderate to severe injury in a large number of orchards, especially where winter injury was present.

Shot-hole borer (*Scolytus rugulosus* (Ratzeburg)) injury was more prevalent than usual in peach orchards. The degree of injury present is not considered to be of consequence since it is present where trees were weakened by winter injury.

Fall webworm (*Hyphantria cunea* (Drury)) defoliation on nut trees, persimmons, cherry and other deciduous trees occurred throughout southern Indiana. It was the most prevalent of any year previously observed. Numerous trees were stripped of all foliage during August.

Livestock Insects

Cattle grubs (*Hypodermia bovis* (L.) and *H. lineatum* (De Villers)) continue to be the number one pest of western feeder stock shipped into Indiana. Greatly increased "gadding" from adult flies on cattle this summer indicates a probable upsurge in grubs in native cattle.

Face fly (*Musca autumnalis* (DeG.)) continues important in the state, but the dry period this early summer coupled with a dry fall kept high populations of this insect restricted to a fairly short period during the middle of the season. Pink eye incidence remained high in cattle excepting those fed supplemental quantities of Vitamin A.

Horn fly (*Haematobia irritans* (L.)) was present in high numbers in August and early September. The unusual summer apparently contributed to this condition.

Horse flies (*Tabanus atratus* (Fab.)) were relatively light this year throughout the state.

House fly (*Musca domestica* (L.)) was a continuing problem throughout the state particularly in areas of questionable sanitation.

Stable fly (*Stomoxys calcitrans* (L.)) was a serious pest at farms where bedding was allowed to become fouled. Where followed, strict sanitation reduced this pest to a negligible level.

Pests of Man and Households

Cat flea (*Ctenocephalides felis* (Bouche)) infestations were numerous after midsummer with many complaints from returning vacationers.

The larder beetle (*Dermestes lardarius* (L.)) appeared in numbers in decidedly more numerous instances than is normally encountered. Many of these occurrences were in and around seasonally maintained dwellings which had not been occupied during the winter of 1962-63, and it has been postulated that the occurrence of these beetles might be related to carcasses of hibernating animals which had expired during this unusually severe season. One larval specimen was collected on cultivated cucumber plant in Tippecanoe County (Hemmerlein). Its occurrence in this situation remains unexplained.

Sap beetles (*Glischrochilus* spp.) were troublesome early in the summer, but the problem was apparently less acute than in 1961 and 1962.

Subterranean termites (*Reticulitermes* spp.) have been the subject of numerous inquiries. If the present interest in preventive treatment is maintained, the economic losses due to the activities of these insects may become significantly lower in future years.

The German cockroach (*Blattella germanica* (L.)) has been the subject of numerous inquiries, but problems with respect to this pest appear to have been less acute than in previous years.

Millipedes of undetermined species have been troublesome during late summer and early autumn. They have been important as occasional invaders of dwellings. The general paucity of information of all kinds regarding this group of arthropods has hampered efforts to attain satisfactory control.

Turf, Tree, Shrub and Forest Insects

Sod webworms (*Crambus trisectus* Wlk. and *C. mutabilis* Clem.) were unusually abundant in lawns for the second straight year. Many lawns in the north-central area of the state were badly damaged. Several previously used insecticides appeared to be relatively ineffective this season.

Bagworm (*Thyridopteryx ephemeraeformis* (Haworth)) populations, although locally heavy on both deciduous and evergreen trees and shrubs, were much lower than normal due to the unusally severe winter of 1962-1963.

Eastern tent caterpillar (*Malacosoma americanum* (Fabricius)) was very common in the pocket area of the state. The most common host was wild black cherry.

Elm leaf beetle (*Galerucella luteola* (Muller)) began its annual population acceleration in June. It was found for the first time at Ogden Dunes on the Indiana-Michigan border.

European pine sawfly (*Neodiprion sertifer* (Geoffroy)) a pest of pine trees in the state, was sparce this season. Few overwintering eggs were laid. Four species of parasitoids were recovered from this sawfly. These are the first records of these natural control agents; they represent the families Bombyliidae and Ichneumonidae.

European pine shoot moth (*Rhyacionia buoliana* (Schiffermuller)) populations were very light this season. The insect is known to be killed by temperatures of -16°F.

Sycamore lacebug (*Corythucha ciliata* (Say)) caused considerable disfiguration of plane trees throughout the state.

Honeylocust mite (*Eotetranychus multidigituli* Ewing) again caused severe defoliation of thornless honeylocust trees. The condition was probably aggravated by the droughty conditions so prevalent in the state.

A leafroller (*Tortrix pallorana* Rob.), an usually severe pest of newly planted pine trees, was of little consequence this season. In June the population was 3% compared to a population of 36% the previous year.

Locust leafminer (*Chalepus dorsalis* (Thunberg)) caused the leaves of black locust in southern Indiana to turn brown early in the summer.

The maple bladder gall (*Vasates quadripedes* (Shimer)) on silver maple were the frequent source of inquiries from many areas of the state where infestations were heavy.

The vein pocket gall (*Itonida* spp.) deformed the leaves of pin oak trees in many areas of S.W. Indiana, and was particularly bad in the Jasper and Evansville areas.

The mimosa webworm (*Homadaula albizziae* Clarke) which has been severely damaging honeylocust and mimosa trees in the southern half of the state was noticeably less abundant in 1963.

The brown race of the oystershell scale (*Lepidosaphes ulmi* (L.)) was more damaging to silver maples this year. Reports were received from many areas of the state. Control measures were necessary to prevent death of the hosts.

Fletcher's scale (*Lecanium fletcheri* Cockerell) caused the thinning of the foliage of many plantings of taxus in the Marion county area.

The cottony maple scale (*Pulvinaria innumerabilis* (Rathvon)) was very abundant on silver maple trees in the Fowler area.

Tuliptree scale (*Toumeyella liriodendri* (Gmelin)), a pest of our state tree, causes much disfiguration by the sooty black mold associated

with its honeydew and the killing of heavily infested branches. It continued to spread and be more noticeable in 1963.

The spruce spider mite (*Oligonychus ununguis* (Jacot)) was unusually damaging to evergreen plantings in the northwest part of the state. Defoliation and necrosis often follows heavy populations.

The smaller European elm bark beetle (*Scolytus multistriatus* (Marsh)), the vector of Dutch elm disease, continues to spread this arboricultural catastrophe in the northern counties of the state.

The pales weevil (*Hylobius pales* (Herbst)) was found again this year in plantations in Warrick and Brown counties. In the latter area, it appeared more numerous.

The tulip tree callous borer (*Euzophera ostricolorella* Hulst), first reported from Indiana in 1961, continues to spread and was found in Owen county in May; this is a new county record.

The bronze birch borer (*Agrilus anxius* Gory) was the cause of the premature demise of many ornamental white birch trees. The condition was probably aggravated by the dry fall of 1962. With the dry conditions now prevalent again this year we can anticipate an even more difficult problem next season.

Zimmerman pine moth (*Dioryctria zimmermani* Grote) continued to spread within the areas already reported to be infested. Populations in a plantation in northern Indiana averaged 20 per cent of the trees in June.

Juniper tip midge (*Oligotrophus* spp.) continued to increase in abundance and spread. A severe pest of cannaert junipers, it kills the new growth buds and the trees become stunted and browned as if scorched by fire.

The Fall cankerworm (*Alsophila pometaria* (Harris)) presented a rather serious problem on maple trees and American elm trees in the Lafayette area in the spring of 1963.

The white-marked tussock moth (*Hemerocampa leucostigma* (J. E. Smith)) was numerous on Norway maples in the Marion county area during late June and early July.

Rose slug (*Endelomyia aethiops* (Fabricius)) skeletonized the foliage of neglected roses in many areas of the state in the fall of 1963.

Walkingstick (*Diapheromera Femorata* (Say)) was again abundant in Starke County oak stands.

Columbian timber beetle (*Corthylus columbianus* (Hopk.)) maintained its low density status in southern Indiana.

Nantucket pine moth (*Rhyacionia frustrana* (Comstock)) was very low in numbers this year presumably due to the severe winter.

It seems appropriate to go on record here and mention a cause of economic loss which is increasing annually and which complicates the assessment of insect damage in certain instances. This situation is that of injurious birds. An example is the corn in southern Indiana. Of the fields examined, 46% had been invaded by birds and 12% of the plants were significantly damaged. Some fields were almost entirely destroyed. Among the birds involved were starlings, red-winged blackbirds, Brewers blackbird and several sparrows.

Notes on the Life History of *Anax junius* (Drury) (Odonata: Aeshnidae)[1,2,3]

JERRY M. MACKLIN, Purdue University

Many authors have suggested the important effects of environmental factors on the growth of Odonata. Photoperiod and temperature were the two factors considered of primary importance in the study reported here.

Anax is a cosmopolitan genus of the 35 to 40 species which are distributed in the temperature and tropical zones. Four species are known from North America, but the range of only one, *A. junius*, enters Canada (28). Furthermore, the genus has been studied by several authors. *A. junius* was selected for this particular experiment because of its wide distribution in America, and because Calvert (5, 6) had previously described its life history and growth rate.

Tillyard (1915a, 1915b, and 1916) reported on the physiological and morphological changes in the early stages of *Anax;* Portman (1921) who was probably the first worker to publish a complete life history for a species of this genus, reared *A. imperator* Leach from egg to adult in a little less than seven months. Later, Calvert (5, 6) reared *A. junius* from egg to adult. More recently, some excellent studies were conducted on *A. imperator* both in the field and laboratory by Corbet (8, 9, 10, 11).

As far as known, Calvert is the only other worker who has published a complete life history for this species. Because he has given an excellent detailed account of the color changes and growth rates which he found and since these observations are similar to his, a detailed description of each instar has been omitted in this paper.

Calvert (6) was able to rear one male from the egg to the adult stage. Using the data obtained from this individual, he assigned various other naiads and exuvia to corresponding instars. In this way he was able to study the growth rates and characters of three short incomplete ontogenetic groups of exuvia loaned to him by Dr. Kennedy as well as many other exuvia and naiads. He concluded that *A. junius* had either 12 or 13 instars, not counting the pronaiad. The individual which he reared moulted 13 times in addition to the pronaiadal moult or 14 times in all. He listed the duration of the immature stage as being 322 to 328 days. He stated, however, that there was no basis for asserting that this naiad presented the normal or typical development of this species. "Its eminence and its usefulness rests entirely on the chance of its having been reared to maturity." Calvert (6).

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1. Purdue University Agricultural Experiment Station Journal Paper 2304.
2. Research from the Entomology Environment Laboratory.
3. Material in this paper formed a portion of a thesis prepared under the direction of Prof. B. Elwood Montgomery and presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Purdue University, August, 1961.

Laboratory Rearing Experiments

On June 24, 1960 a female *A. junius* was seen ovipositing alone at a small gravel pit about one mile south of the Purdue University campus. She was captured and taken to the laboratory alive, where she was induced to oviposit a few eggs. Her wings were placed between pieces of cork board and stiff paper, in a manner similar to that used for spreading freshly-killed dragonflies for display purposes. The body was supported by the wings, however, because there was no center board. This simple apparatus was then placed over a dish of water containing a soft water-soaked piece of wood. The legs and abdomen of the female were allowed to come in contact with the wood, and about an hour later, she was seen ovipositing in a more or less normal manner. About thirty eggs were secured in this way. This method is similar to that suggested by Gardner and MacNeill (13) for securing eggs of species which oviposit exophytically.

The eggs were kept at a room temperature of 68°-80°F. On July 5, 1960, 20 second instar naiads were found in the dish.

Rearing studies were then started in a controlled environment chamber described by Macklin (20). The temperature was maintained at 80°F. and the day length was set at 17 hours continuous light in each 24 hour period. These specific conditions were selected in an effort to determine if a diapause could be initiated in this species as it was in *A. imperator* by Corbet (10).

The naiads were separated into individual culture dishes and 10 were placed in a constant environment chamber, the others were placed in similar dishes outside. The culture dishes, 4½" in diameter and 1½" deep, were filled with water to which protozoa cultures were added to supply the naiads with food. The dishes were covered with glass plates to prevent evaporation.

All of the naiads outside and one naiad inside the chamber died within the next three days. The death of the naiads outside the chamber may represent the normal mortality rate, or it may have been caused by the relatively high room temperature, which was nearly 95°F. during part of this period.

Five of the surviving naiads were placed outside the chamber, but none of these survived the third instar. Of the four remaining naiads kept inside the chamber, only one, a male (#606), reached maturity. This individual moulted only 11 times, counting the pronaiadal moult as the first, and completed immature growth in 111 days including the egg stage (Table 1). Although it is unfortunate that no other naiads matured from these eggs, the data for naiad #606, can be compared with Calvert's data and with the data from other partial rearings carried out in the constant environment chamber. The principal value of these rearing experiments lies in the fact that they show considerable deviation from the study made by Calvert, and also answer some of the questions which his study raised.

TABLE 1

Comparative data for two A. *junius* naiads reared from egg to adults, developing in 111 days in 11 instars, and 341 days in 14 instars.

Instars	Moult Date[a] (Macklin) #606	Moult Date[a] (Calvert) #3	Days of Duration #606	Days of Duration #3	Number of Segments Tarsi #606	Number of Segments Tarsi #3	Number of Segments Antennae #606	Number of Segments Antennae #3	Length in mm. #606	Length in mm. #3	Head Width in mm. #606	Head Width in mm. #3	Length of rear wing-sheaths in mm. #606	Length of rear wing-sheaths in mm. #3
Egg[b]	6-24	7	11	18										
1[c]	7- 5		few minutes											
2	7- 9	8	4	8+	1	1	3	3	2.6	2.45	1.0	.73		
3	7-15	8	6	14	2	2	3	4	4.4	2.82	1.6	.9		
4	7-18	9	3	15	2	2	4	4	5.3	3.35	1.7	1.23		
5	7-20	9	2	3	2	2	4	4	8.9	3.68	2.5	1.39		
6	7-25	9	5	11	2	2	lost	5	11.5	7.36	2.8	1.92	0.4	.14
7	7-30	9	5	4	3	3	5	5	14.5	10.14	3.5	2.49	0.6	.22
8	8-10	9	11	9	3	3	6	5	20.1	14.0	4.2	3.03	1.09	.33
9	8-20	10	10	14	3	3	7	6	27.7	18.0	5.3	3.76	1.7	.57
10	9-13	2	2	131	3	3	7	7	35.0	22.5	6.7	4.62	3.8	1.06
11	10-13	3	30	23	3	3	7	7	36.0	29.5	8.2	5.56	8.4	1.72
12		4		28		3		7		38.0		6.54		2.74
13		5		21		3		7		44.0		7.61		5.24
14		6		42		3		7		47.0		8.5		10.39
Total			111	341										

a. month and day for #606, month only for #3.
b. deposited by female in laboratory.
c. pronaiad counted as 1st instar, not observed.

Comparison of Immature Stages

By comparing the characteristics of naiad #3 of Calvert (6) with naiad #606, it was found that the latter appears to skip certain instars and combine the characteristics of some others (Table 1).

Considering the time duration found for the instars as shown by Table 1, much variation is evident. The longest (10th) instar of Calvert's naiad #3 required 131 days to complete. This period from October to February is "the winter diapause, spent in a moderately heated room and during which the larva fed. At other times of the year this instar may be reduced to twelve days,—" (Calvert 6).

By comparing the total length of naiad #606 with the lengths listed by Calvert, it would appear that transformation took place when this naiad reached a size equal to the 11th larval stadium or the 12th instar of his naiad #3. If instars two to 11 for naiad #606 are compared with instars two to 12 for Calvert's naiad #3, and if the minimum number of days (12) cited by Calvert is substituted for the 131 day period of this 10th instar of #3, then it will be found that the two naiads made about the same growth in total length,—38 mm. (#3) and 36 mm. (#606) in 141 days and 96 days respectively.

Other Rearing Experiments

Seven naiads were collected from the same gravel pit at which the ovipositing female of *A. junius* was taken. Two of these naiads were collected in January, four in June, and one in August, 1960. Because these naiads were selected on the basis of size, they do not represent the average sample from the pit during these periods. The smallest naiads found during each collecting trip were placed in the constant environment chamber for rearing.

The number of days each of these naiads spent in the various instars as compared with naiad #606 is shown in Table 2. Of the seven naiads collected in nature, six were reared to the adult stage. One of these moulted eight times, four moulted seven times, one moulted two times, and one died during transformation to the adult stage after four moults.

The penultimate and ultimate instars tend to be longer than the earlier instars. It also appears that the naiads which were collected in the latter instars, such as the quintult and tertult, had a longer ultimate instar than those which were placed in the chamber at an earlier stage. In general, it would seem that *A. junius* naiads living in similar conditions, such as the warm shallow water near the shores of a pond, and having at least ten to 15 hours of daylight each day could be expected to mature quite rapidly. Naiad #634 completed its last seven instars in 104 days and naiad #606 made its total growth, eleven instars, in only 100 days. Because the naiads which were placed in the constant environment chamber in the earlier instars developed much more rapidly than the naiad reared by Calvert, it is assumed that the conditions inside the chamber were favorable.

The extreme variation found between the number of days required for the different naiads to complete the same instar may be attributed partly to the time of year when they were collected.

TABLE 2

Number of Days in Each Instar for Eight *A. junius* Naiads Reared in a Constant Environment Chamber

Specimen Number	Sex	Instar										
		Decimult	Novult	Octult	Septult	Sextult	Quintult	Quartult	Terbult	Penult	Ult	Total
469	M			7[a]	30	7	7	17	20	26	24	138
470	F			9[a]	23	11	5	16	16	29	24	133
570	F		3[a]	3	4	1	4	7	18	26	41	107
572	F						2[a]	8	23	31	47[b]	111
573	F								8[a]	30	69	107
574	F			2[a]	4	2	5	12	20	31	36	112
606	M	4	6	3	2	5	5	11	10	24	30	100
634	M			8[a]	5	5	5	5	14	15	24	81
Average		4	6	3	11.33	5.17	5.17	10.86	17.29	26.50	36.88	

a. Naiad required this number of days to complete the instar in the chamber, but the total duration of the instar is not known.

b. Died in transformation.

Average number of days includes only naiads in the chamber during the complete instar.

F—Female.

M—Male.

Compared with naiad #606, the growth rate of naiad #634, which was collected August 28, 1960, was quite rapid. Although the octultimate and septultimate instars of #634 were somewhat longer than these same instars for #606, it is interesting to note that #634 completed the last seven instars in only 73 days as compared to 87 days for #606. Naiads #570 and #574 which were collected on June 20, 1960, matured more slowly in the last three instars than did naiads #606 and #634. Although an accurate comparison cannot be made because of the different photoperiods, it may be noticed that the naiads collected in midwinter required a much longer time in the first instar following their collection than did the others; naiad #469 and #470 which were collected on January 3, 1960, spent 30 days and 23 days respectively in the septultimate instar as compared to two to five days for the others. If it is assumed that growth is nearly stopped during the winter, it would only be natural for these individuals to be somewhat slow in starting to grow after having been taken from this cold natural environment where the air temperature was 27°F. and the surface water temperature was 32.5°F. They were collected from bottom debris about four feet below the surface and 15 feet from the south edge of the pond.

Naiads #572 and #573 which were collected in the quintultimate and terultimate instars developed more slowly in the final instar than did the other naiads collected on June 20, 1960. In fact, these two naiads required more time in the penultimate and ultimate instars than did the naiad reported by Calvert. This naiad spent only 21 days in the penult instar and 42 days in the ult compared with 30 and 31, and 47 and 69, respectively, for these instars in #572 and #573. The growth rates of these naiads in nature were probably not altered very much by the constant environment. There is, of course, the possibility that other factors caused these naiads to mature more slowly in the final instar. Grieve (15), for example, found that parasites lengthened the growth period of *Ischnura verticalis* Say. However, one should not overlook the possibility that this variation in growth rate may occur commonly in this species.

Variations in Size of Reared Naiads

The naiads reared in the constant environment chamber show a rather wide range of variation in size, but it does not appear to be much different from the finding of Calvert for this species, and it is much less than the differences cited in the literature by other authors. The ultimate instar exuvia of the eight naiads which were placed in the constant environment chamber ranged from 36.0 mm. to 46.9 mm. in total length, and from about 8.2 mm. to 8.9 mm. in head width. Cabot (3) listed a total length of 40-52 mm. for this species. Needham and Hart (22) gave the total length as 39 mm. and the head width as 8 mm. Garman (14) listed the total length of mature naiads as 50 mm. Needham and Westfall (23) referred to the length of the naiads in terms of the genus only; they gave the total length as 40 mm. to 62 mm. Walker (28) listed 43.5 mm. to 47.0 mm. for the total length. Corbet (10) found that mature *A. imperator* naiads varied from 44 mm. to 56 mm. in length. The males were usually about one millimeter shorter than the females.

The length of the front margin of the rear wing-sheaths of the naiads reared in the constant environment chamber ranged from 8.2 mm. to 10.4 mm. Naiad #574 measured 39.7 mm. in length but the rear wing-sheaths were only 8.2 mm. long. In addition, the sizes of the adults did not vary in direct proportion to the ultimate exuvia. Naiad #634 which measured 46.7 mm. in length was much longer than naiad #606 which was only 36.0 mm. long, but the abdomen of the adults of naiads #634 and #606 measure 52 mm. and 49.2 mm., respectively. The naiad of the only other male placed in the chamber, #469, was 45.1 mm. long and the abdomen of the adult emerging from this exuvia was 51.6 mm. in length.

Discussion and Conclusions

In order to clarify some of the points raised by Calvert (6), it is necessary to discuss the seasonal distribution of *A. junius*. Montgomery (21) studied the distribution and relative seasonal abundance of this species over a 41-year period from 1900 to 1940 inclusive (Figure 1). According to his findings, adults of *A. junius* are found on the wing from the first third of March to the last third of October in Indiana. No population peaks which would indicate a synchronized emergence are shown. Whedon (29) observed this species ovipositing in Minnesota (44° North Latitude) as early as the 5th of March. He stated that, "Undoubtedly this large dragonfly is to be found very commonly over the entire state from April to November." Naturally, one would expect to find them flying earlier in the south. Blatchley (1) reported them at Sarasota, Florida, on February 17, 1911, and Calvert (4) stated that Skinner took a male at Guantanomo, Cuba, February 13, 1914.

The long flight period and consequently, the extended mating season as well as some unique field observations have led other authors to believe that *A. junius* matures in a comparatively short period of time. Paul Fischer (12) wrote: "In Franklin Park, in this city (Columbus, O.) a small lake was dug last winter in a place which was before entirely dry and well-drained, and during the last of April and the first of May this lake was filled with water from the city waterworks' pipes, which I am sure contain no dragon fly nymphs; and on the 30th day of August last, the shores of this artificial lake were literally lined with the exuvia of *Anax junius* nymphs; so they could not have been older than four months at the utmost."

Kellicott (18) interpreted Fischer's observation as appearing "to show that in this species, at least, imagoes mature from eggs laid the same season." Needham and Hart (22), referred to Kellicott and drew the conclusion that this indicated "the occurrence of two broods in a year. This is confirmed by one of our experiments, half-grown larvae were placed by Mr. Hart in a breeding-cage June 16 reaching the imago stage August 4." Brimley (2) also made an interesting observation. He stated "During the late summer of 1902, the water in Green's rock quarry (North Carolina) dried completely up, and remained so for at least two months. Unfortunately, I did not notice the dates when the pool dried and when it filled up again. On July 22 and August 10, 1903, I found in the quarry exuviae of recently transformed *Anax junius;* on Sep-

tember 5, 1903, of *Tramea carolina;* on August 10, of *Lestes forcipatus;* on August 10 and 18, of *Pachydiplax longipennis;* thus apparently showing that these four species had in this case completed their transformation in less than six months. The quarry had not had any water in it in the previous fall before late November at the earliest; thus, the eggs of these species must have apparently been deposited in the spring of 1903."

Based on the fact that 341 days were required to rear naiad #3, Calvert (6) concluded that: 1. Hart's experiment may possibly have speeded up the growth rate owing to food, the higher temperatures of June and July and other laboratory condition," 2. in Brimley's case, eggs were probably laid in November of the previous year; and, 3. in Fischer's case, partly grown naiads were introduced into these waters by artificial means. Calvert suggested that "in spite of his (Fischer's) assurance to the contrary, larvae of the eighth instar of younger, of a body length of 14 mm. or less, were introduced by the water pipes or otherwise."

Kennedy (19) who mentioned only *junius* in the genus stated that "*Anax* has speeded up its life cycle to three months." Wilson (30) said "Some species of *Anax, Tramea,* and *Aeschna* may have two broods during the year."

Calvert (6) summed up his observations as follows: "The existing breeding evidence does not admit of the occurrence of two successive generations within a year in temperate North America. Under continued high temperature of both water and air, either in nature or in the laboratory, two generations per year may be possible, but this has yet to be demonstrated."

The rearing experiments described in this paper have now demonstrated this possibility and tend to support the field observation made by Fischer and Brimley.

We are now faced with the question of whether *A. junius* has a winter dormancy or diapause as was suggested by Calvert which would delay development until late spring or early summer and therefore, prevent the occurrence of two generations in a single year. Jenner (16) stated, "there is no evidence at the present time to indicate that low temperature promotes diapause in any nymph of any species of Odonata." However, Corbet (11) found what appeared to be a diapause in *A. imperator* which was induced by changing the photoperiod.

The threshold of optical stimulation of naiads is another question to be considered. It has been suggested that the threshold of activity for the Odonata is below the intensity of moonlight (17).

The fact that naiads #469 and #470 had moved out into newly filled parts of the gravel pit on January 3, 1960 even though ice was covering most of the pit, indicates that they were not completely dormant. Therefore, it seems probably on February 27 that growth, if stopped, during the winter, starts quite early in the spring. Water temperature at the four foot depth from which these naiads were taken, was 45°F.

A. junius unlike *A. imperator,* matures in relatively large numbers throughout the season (Figure 1). This would indicate that it does not

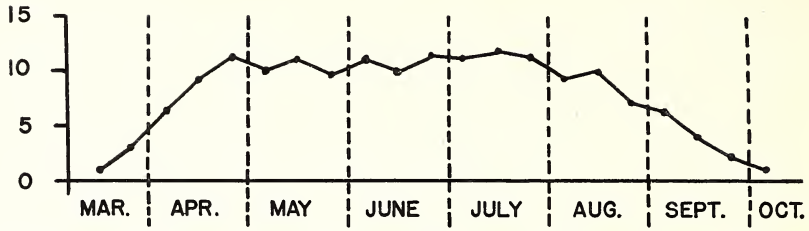

Figure 1. Flight season range and relative seasonal abundance of *A. junius* Drury in Indiana. Numbers are tabulated by thirds of months plotted as the "moving average" (average of three successive periods plotted at the midpoint) of collections or observations made during the period 1900-1940 inclusive. (Modified from Montgomery, 1947.)

have a diapause which synchronizes emergence. A long day-length of 17 hours employed in these rearing experiments was selected because Corbet (10) found that a constant long photoperiod of 15 hours and 20 minutes appeared to induce a diapause in *A. imperator*. No such diapause seems to be present in *A. junius*.

Even if *A. junius* were subject to a control mechanism which would induce a diapause such as is known for *A. imperator*, the day length and water temperature both increase under normal conditions in this area until the latter part of June.

Using nautical twilight at the 40° latitude (the approximate latitude of Lafayette, Indiana) it may be found that a 17 hour day occurs as early as April 21, and using astronomical twilight, this day length is encountered at this latitude on March 27.

If adults of *A. junius* emerged on March 15 and required two weeks to become sexually mature, they could lay eggs by the first of April. These eggs would have about 90 days in which to hatch and mature before the day lengths began to shorten. It is possible, of course, that the eggs in nature would not hatch as quickly as they did in the laboratory. Nevertheless, the naiads from these eggs could be in the penultimate or ultimate instar by the first of July. They would still have more than a hundred days, in some years, in which to complete their growth before the end of the flight period.

In view of these rearing experiments and the field observations indicated, it would appear that adults of *A. junius* emerging in March and April could lay eggs that would become adults during the same season in this area and, therefore, give rise to a second generation the same year.

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The Control of Sod Webworms (*Crambus spp.*) in Indiana[1]

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Three species of sod webworms caused serious damage to turf in Indiana during the summers of 1962 and 1963. The three species were: *Crambus trisectus* (Walker), *C. mutabilis* Clemens (1) and *C. alboclavellus* Zell. (4). *C. trisectus* was the most abundant species caught in both black light and emergence traps. *C. mutabilis* was taken only in the larval stage from samples of sod. *C. alboclavellus* Zell. was taken in small numbers only in black light traps adjacent to the Purdue campus.

The larger sod webworm, *C. trisectus*, was present from early spring until fall. This information is similar to that reported by Ainslie and Crawford (2, 3). Swarms of adult moths flew, in zig zag fashion, across lawns whenever they were disturbed. Large numbers of these snout moths could be seen congregated around porch lights during the evening hours. The insect has been of periodic importance since 1915 (2). Food plants of the webworm include blue grass, crabgrass, the various crop grasses such as corn, wheat, oats and timothy and it can subsist on clover (2).

Both *C. trisectus* and *C. mutabilis* are reported to overwinter as larvae (1, 2). Both regularly have two generations per year, but may have a partial third generation depending upon the season (2, 5, 6).

During the past two growing seasons chlordane, the normally recommended turf insecticide, failed to give lawns the necessary pro-

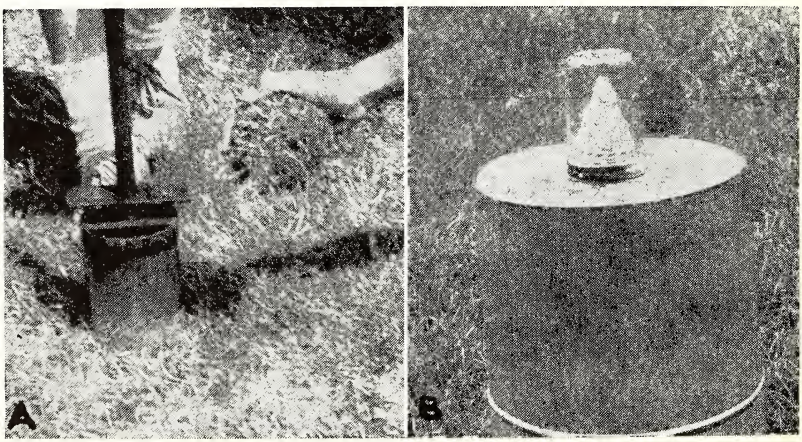

Figure 1.

A. A sod plug used in evaluating the effectiveness of the sod webworm experiment, and the tool for the procurement of the sample.

B. Lard can traps used to capture the adult sod webworms as they emerged from treated sod.

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1. Contribution from Purdue University, Agricultural Experiment Station Journal Paper No. 2257.

TABLE 1

A comparison of insecticide treatments against the sod webworm, Lafayette, Indiana, 1963

Insecticide and Concentration of Granular Formulation	Amount of Material Applied (ozs.) per 1000 sq. ft.	Amount of Actual Toxicant (ozs.) per 1000 sq. ft.	Avg. No. of larvae or pupae[1]	Avg. No. Moths captured from 7/18 to 10/14
Exp. Compd. Bayer 29493 5%[2]	16.3	.8	.8	.2
Dylox 5 %	47.2	2.4	1.6	.8
G. C. 4072 10%[3]	8.2	.8	1.8	.6
Dieldrin 5%	26.6	1.4	2.0	.4
Sevin 10%	39.0	3.9	2.4	1.8
Diazinon 10%	32.8	3.3	2.8	.8
Kepone 2%	16.7	.33	3.4	2.0
Heptachlor 2½%	38.9	.97	3.6	1.4
Disyston 2%	24.6	.48	4.0	1.8
Aldrin 10%	38.9	3.9	5.6	0
Check—untreated	——	——	4.4	1.4
L.S.D. 5%			3.0	1.4
L.S.D. 1%			4.0	1.7

1. Average number of larvae found in 4 soil plug samples containing 25.1 cu. in. each. Samples taken July 12 and August 9.
2. 2.0,0-dimethyl 0-[4-methylthio)-m-toly] phosphoro-thioate.
3. Diethyl-1-(2,4-dichlorophenyl)-2-chloroylnyl phosphate.

tection and many lawns were badly damaged. Therefore during the summer of 1963 an experiment was conducted to check the possible effectiveness of several other insecticides, in granular form, against sod webworm infestations in two lawns in West Lafayette, Indiana. The plots 7′ by 14′ containing 98 sq. ft., were treated with 10 different granular insecticide formulations on June 27th, at the approximate end of the first adult emergence. A Gandy granular applicator, 7′ wide, mounted on bicycle wheels with a throw-out clutch, was used to make the applications. The experiment was replicated five times.

Effectiveness of the treatments was ascertained by taking two sod plug samples containing 25 cubic inches from each plot on July 12th and August 9th. Each sample of grass was then shredded and the number of larvae and pupae counted. See figure I. A second method of evaluation consisted of trapping the adults as they emerged from the treated turf of each plot. For this purpose a trap was constructed from a 5 gallon lard can, a wide mouthed pint Ball mason jar and a cone shaped Dixie cup. The area covered by each trap was 103.9 sq. in. and the trap was located in the approximate center of each plot. The traps were installed on July 18th and the numbers of moths captured were tabulated until October 14th.

The results of this experiment are shown in table 1.

The results of this experiment indicate that the most effective insecticides tested were two experimental compounds, Bayer 29493 and G. C. 4072, followed closely by Dylox and dieldrin. It is interesting to note that several insecticides commercially recommended for sod webworm control, sevin, kepone, diazinon and disyston, were less effective, and not significantly different from the untreated check. At the time the experiment was applied no chlordane granules were available, but Heptachlor, which contains some of the active ingredients in chlordane was included and failed to give adequate control of the sod webworm larvae and adults.

The enigma of why the aldrin plots contained so many webworm larvae and did not yield any adults might be explained by the fact that aldrin is converted to dieldrin, thus the larvae may have been killed before they became mature.

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Periodical Cicadas in 1963, Brood 23[1]

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In 1961, Hamilton (1) summarized investigations made on periodical cicadas (*Magicicada* spp.) and discussed the injury that they cause in apple and peach orchards. Emphasis was placed on "tree decline" of apples caused by feeding of cicada nymphs on the roots of the trees.

The purpose of this discussion is to summarize information obtained since 1961, especially in reference to the 13-year Brood 23, which emerged in southwestern Indiana in 1963. Reference will also be made to distribution of 17-year Brood 3, since adults from it also emerged in western Illinois, and to reports of the appearance of cicadas in other States in 1963. Data reported were obtained on emergence, oviposition, and hatch of eggs in or in the vicinity of orchards in Knox and Sullivan Counties, Indiana and Lawrence County, Illinois.

Adults began to emerge along the Wabash River north of Vincennes on May 19, first in areas where the sun shone directly on the soil, oftentimes along the edges of timbered areas or where the trees had been removed since 1950. By May 20 heavy emergence started in open areas, where orchards or trees had been removed. There was little or no emergence under trees or in shaded areas until May 24 when adults began coming out in large numbers. Time of day that emergence occurred was not observed, but it was estimated that to be early in the morning at predawn. Minimum daily air temperatures were 60° C. or above when mass emergence began. Lower temperatures, just prior to May 24, seemed to be holding back emergence. Peak emergence occurred between May 24 and 31. As nearly as could be determined, emergence was completed June 2. By July 2, practically all adults had died; only an occasional adult could be seen in the woodlands, and none were found in apple orchards.

The ability of cicada nymphs to develop and emerge as adults under adverse conditions was demonstrated in an area along the Illinois bank of the Wabash River, 5 miles north of Vincennes, where heavy emergence of adults occurred in 1963. This area was subjected to flood waters 34 different times between December 7, 1950 and June, 1963, as shown by the following tabulation:

Egg laying began in the Vincennes area on June 3. Movement of adults from tree to tree and from wooded areas into adjacent orchards increased at this time. Peak oviposition occurred June 6 to 10. The tempo of adult movement during this period was exceptionally high and movement into orchards near wooded areas was very high. For example, a 3-year-old peach orchard planted in an open field just west of Lawrenceville, Illinois, that was as least ½ mile away from the nearest emergence area, was severely injured. Oviposition was completed by June 20.

1. Ms. Ent. 3117.

Occurrence of floods in area along Wabash River where cicada emerged in 1963[2]

Year	No. Times Under Water	Year	No. Times Under Water
1950	1	1958	4
1951	4	1959	3
1952	6	1960	3
1953	1	1961	2
1956	2	1962	2
1957	5	1963	1

Hatching of eggs started near Vincennes on July 26, reached its maximum August 1, and was last observed August 12. Apple limbs on trees in heavily infested orchards in which cicadas were active were found with six oviposition cuts per linear inch of wood, each with an average of 13 eggs, or about 76 eggs in each inch of injured wood.

At the time of hatching, the embryo within the egg begins to wiggle, or move. This causes the egg to move forward in the oviposition cut until it reaches the open air at the outside of the cut. At this point the shell breaks, the nymph wiggles out and forward, so that the egg shell remains attached to the twig on the outer portion of the oviposition scar. The nymph pauses on the twig at the mouth of the oviposition scar momentarily, then drops to the ground, and immediately disappears in the soil. Eggs within a single oviposition puncture hatch singly with the one nearest the mouth (outer opening) of the oviposition scar hatching first. They hatch at intervals of 5 seconds. A live embryo is capable of bypassing a single dead egg within the oviposition puncture, but a composite of several dead eggs blocks the passage enough to prevent further hatch from that particular puncture.

According to Alexander and Moore (2) there are six species of periodical cicadas, three of which require 13 years to complete their life cycle. These are *Magicicada tredecim* (Wabash and Riley), Riley's 13-year cicada, *Magicicada tredecassini*, Cassin's 13-year cicada, and *Magicicada tredecula*, the little 13-year cicada. They predicted that a brood emerging within a given year would be comprised of individuals from the three species. Collections of recently emerged cicadas, taken at random, contained all three species as shown in the following tabulation: *M. tredecassini* and *M. tredecim* were far more prevalent than *M. tredecula*. Identification of 701 specimens, collected on several occasions during the adult flight period, showed 70 percent *M. tredecassini*, 29 percent *M. tredecim*, and 1 percent *M. tredecula*. These collections also indicated that males emerged earlier in the season than females.

2. Data from Wm. Frisz, U. S. Weather Bureau, Vincennes, Ind. This area was under water a total of 454 days during this period, and at one time was covered with water for 34 days. During the highest flood period more than 12 feet of water covered the area.

Collections of periodical cicadas by dates, 1963

Date Collected	No. Specimens Collected	Percent of Collections That Were					
		M. tredecassini		*M. tredecim*		*M. tredecula*	
		Total	Males	Total	Males	Total	Males
May 23	32	34	91	56	89	9	100
May 28	34	15	80	70	33	15	80
June 7	34	44	0	56	11	0	—
At random thru season	701	70	29	29	53	1	57

Records obtained on the appearance of Brood 23 involved 14 orchards in Sullivan, Knox, Gibson, and Vanderburg Counties, Indiana, and 30 orchards in Crawford, Lawrence, Randolph, Jackson, Union, and Calhoun Counties, Illinois. Cicadas reported in 3 orchards in Pulaski, McDonough, and Fulton Counties, Illinois, are believed to represent 13-year Brood 3. Brood 23 was also reported from Kentucky, Tennessee, and Missouri and Brood 3 from Lee County, Iowa.

In Indiana emergence of Brood 23 in 1963 involved 400 acres of apples and 225 acres of peaches. In the tri-state area of Indiana, Illinois, and Kentucky, it involved approximately 1,652 acres of apples and 900 acres of peaches.

Control Investigations

Most of the growers timed applications of carbaryl sprays to reduce populations of cicada adults within their orchards during the preoviposition period. Such sprays generally killed most of the adults they came in contact with. However, because of the extended emergence period, at least four applications were necessary at about 5- to 7-day intervals to assure reductions in oviposition. At the peak of egg-laying (June 7-10) adults moved from tree to tree throughout the day in dense droves. Many orchards within the infested area, adjacent to untreated woodland, were quickly reinfested with females that laid eggs rapidly; control measures failed in many places during this attack. It was evident that future recommendations for control of cicada outbreaks in orchards should include aerial sprays of surrounding woodlands.

Tests in which corrugated paper bands were dipped in spray solutions of carbaryl, Bayer 37344 (4-(methylthio)-3,5-xylyl methylcarbamate), an experimental carbamate from Union Carbide, Zectran® (4-dimethylamino-3,5-xylyl methylcarbamate), and an experimental carbamate from the Mobil Corporation at 8 ounces and 1 pound for 100 gallons, allowed to dry 24 hours, and then exposed to 30 adult cicadas, showed that the experimental carbamate from Union Carbide effectively knocked down all adults rapidly (within 3 hours) at both dosage levels. At the 1-pound dosage level, following 24- and 48-hour exposures, Zectran was significantly more effective than carbaryl and carbaryl was a little more so than Bayer 37344. The experimental carbamate from

the Mobil Corporation was also effective. These conclusions were confirmed by field-laboratory studies in which adult cicadas were caged with sprayed leaves from field plots and by observations made in orchard plots at two separate locations. In the field tests the materials included in the laboratory dipping experiments were applied at 1 pound per 100 gallons of water four times at 7-day intervals during the period of adult activity.

Field plots were also treated for cicada control July 30, or about the time eggs began to hatch, with sprays containing 1 pound carbaryl, an experimental carbamate from Union Carbide, or Zectran per 100 gallons or 6 ounces demeton, phorate, or dimethoate applied to the trees or to the ground under the trees (set up as two separate experiments). The ground treatments were also repeated in the greenhouse, where apple seedlings with newly hatched nymphs placed in each pot were used. Results have not yet been determined.

Hamilton (1) reported the application of a series of soil treatments to individual trees in the Bessire Orchards, Nashville, Indiana, where nymphs from the 1953 emergence of the 17-year Brood 10 were causing severe tree decline. At the time of the report in 1961, available evidence did not indicate that these treatments, applied in the fall of 1960 and spring of 1961, had been effective.

However, examinations of these plots during the growing seasons of 1962 and 1963 very definitely showed that tree decline was corrected where wettable powder formulations of carbaryl or phorate were injected into the soid beneath the trees. In 1963, vigor of fruit set on treated trees appeared to be normal. The improvement in vigor was first noticeable in 1962, 1 year after treatment had been made. However, when carbaryl was applied to the soil surface and worked into the soil with a tree hoe, it did not correct tree decline. The following data show the effect of these treatments on the yield of apples in 1963:

Soil Injection Treatments	Number Apples Per Tree
May 18, 1961—Variety Grimes	
Phorate 10 oz./tree	1651
Carbaryl 10 lb./tree	1096
Untreated	2
October 4, 1960	
Carbaryl 2½ lb./tree	
Grimes	587
Red Delicious	601
Untreated	
Grimes	2
Red Delicious (2 trees)	100; 234

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GEOLOGY AND GEOGRAPHY

Chairman : William Kowitz, Valparaiso University

John Fraser Hart, Indiana University, was elected chairman for 1964

Geology of Sabine Lake and Vicinity, Louisiana and Texas

Henry E. Kane,[1] Ball State Teachers College

Location

Sabine Lake, a lake estuary (11), is situated in the extreme southeastern corner of Texas and the southwestern corner of Louisiana, in a portion of the North-Central Gulf Coastal Plain. The northern boundary of the lake is approximately at lat. 29° 59′ N.; the southern at lat. 29° 45′ N.; the eastern at long. 93° 45′ W.; the western at long. 93° 57′ W.

General Geology

Structurally, the Gulf Coastal Plain is a homocline with gulfward dipping strata disturbed locally by normal faulting, folding, and salt dome uplifts. The age of the geomorphic and stratigraphic features of the province with which this study is concerned is Late Pleistocene and Recent.

Significant geological contributions about southeast Texas have been made by Bernard (2) and about southwest and central Louisiana by Fisk (3), Holland and others (9), Howe and others (10), and Welch (16).

In Louisiana, four Pleistocene terraces have been recognized by Fisk (3). These terraces, representing deltaic deposits coastwise and equivalent fluviatile deposits up the valleys, are designated, from youngest to oldest, Prairie, Montgomery, Bentley, and Williana. Bernard (2) extended the correlation of these terraces (formations) from Louisiana into southeast Texas and applied the same formational names. He considered that part of the Prairie formation of Louisiana flanking the Gulf equivalent to the Beaumont clay of Texas.

In addition, Bernard (2) recognized in southeast Texas a surface between the Pleistocene Prairie terrace and the modern flood-plains of the Neches and Sabine rivers which he designated Deweyville. The youngest surface recognized is the modern-day floodplains with their equivalent coastwise marsh, bay, and associated deposits. The modern surfaces are Late Recent in age, with the Deweyville considered of questionable Early Recent age.

Surface Geology

The Late Quaternary geology of the study area consists of the Pleistocene deltaic plain of the Neches and Sabine rivers in the northern

1. Acknowledgments are made to Shell Development Company for its financial grant toward this project and to the Gulf Coast Association of Geological Societies for permission to publish Figures 1 and 2.

part and the Pleistocene deltaic plain of the Trinity River in the western part (see fig. 1). These deltaic deposits, with interbedded marine and lagoonal facies, form an extensive coastwise plain (1),

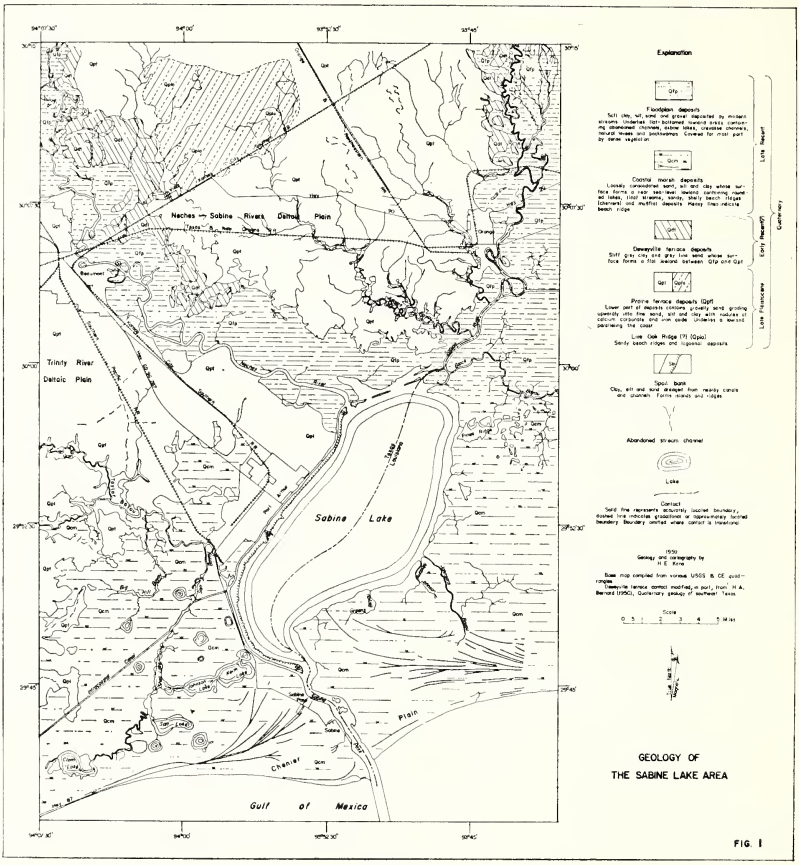

Figure 1

which has been designated the Prairie terrace and which can be traced into fluviatile equivalents up the valleys. Remnants of this terrace representing dissected stream divides occur in Louisiana near Black Bayou. Other remnants and ridge extensions of the terrace occur in the western part of the area.

Associated with the Prairie terrace, in the northern part of Orange County, near Mauriceville, Texas, are sandy beach accretions and associated lagoonal deposits, referred to as the Live Oak Ridge (?) or Ingleside shoreline (13). These deposits, rising approximately ten feet above the surrounding Prairie terrace level, result from a Late Pleistocene stand of the Gulf of Mexico. Subsequently, this shoreline was bypassed by the regional drainage as deltas were built seaward. According to

Price, this shoreline can be traced in discontinuous segments from Matagorda County, Texas, to Calcasieu Parish, Louisiana.[2] Henry (8) posits a possible correlation with the Pamlico shoreline of Florida, which occurs at a 25-foot elevation.

South of the Pleistocene outcrop is the Recent coastal marsh; equivalent fluviatile deposits extend up the valleys of the Neches and Sabine rivers. The fluviatile deposits of the two rivers include the Deweyville terrace and the modern floodplains. The coastal marsh toward the Gulf margin includes the chenier plain (14), consisting of abandoned sandy and shelly beach ridges and associated mudflat and marsh deposits.

Subsurface Geology

The sedimentary material of the oxidized Pleistocene lying beneath the Recent fluviatile and marsh deposits is a stiff, vari-colored clay, bluish-gray, red, brown, yellow, or tan, sometimes containing concentrations of lime or iron nodules. In a few cases, the uppermost material of the oxidized zone consists of whitish, very fine sand or silt. The Pleistocene clays were usually very difficult to penetrate with a probe or auger.

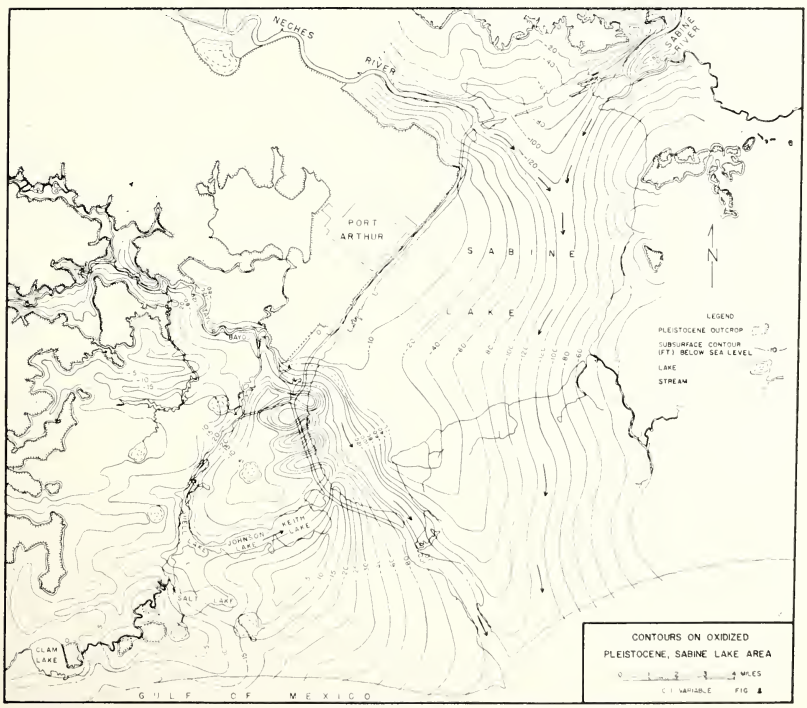

Figure 2

2. In personal correspondence, dated September 24, 1949, with Bernard (1950).

In contrast, the Recent sediments consisted of grayish or blackish soft clays and silts with grayish or whitish compact sands. The clays were penetrated very easily by auger; the thick sands resisted penetration. In some logs and borings in Taylor Bayou and Sabine Pass, great thicknesses of sand were encountered in the basal section of the Recent sediments.

Subsurface contours on top of the oxidized Pleistocene reveal the confluence of the Neches and Sabine rivers at the north end of the lake (see fig. 2). The valley of the combined streams is entrenched to a minimum depth of 120 feet. The axis of the valley trends generally north-south through the eastern part of Sabine Lake, then through the western portion of Cameron Parish, Louisiana, approximately four miles west of Johnsons Bayou. The western side of the valley merges with the Pleistocene outcrop flanking Sabine Lake on the west. The Pleistocene stream divides in Louisiana indicate that tributary streams entered the valley from the east, probably giving an embayed appearance to this part of the valley wall. The same interpretation might apply to the western wall, but substantiating evidence is lacking.

A narrow stream divide projects southwardly from the main Pleistocene outcrop on the western side of the entrenched valley of the Neches and Sabine rivers, separating it from the entrenched valley of Sabine Pass.

The valley of Sabine Pass, with steep and highly embayed walls as indicated by a portion of its western valley wall, is entrenched to a minimum depth of 120 feet. This valley, which trends southeast, represents the southern continuation of the present Taylor Bayou valley. The trend of the valley suggests that it might be tributary to the main entrenched valley of the combined Neches and Sabine rivers. Presently, the valley of Sabine Pass functions as the tidal outlet of Sabine Lake.

Subsurface ridges extend from the Pleistocene outcrop on the extreme western side of the study area toward the Shell Lake-Clam Lake drainage system. Some Pleistocene outliers also occur. This area is separated from two main subsurface "hills" by the valleys of Shell, Johnson, and Keith Lakes, and Salt Bayou, all of which flow around the flanks of the northernmost of these "hills." The lakes drain into Sabine Pass, and Salt Bayou flows into Taylor Bayou.

Fisk (4), using information based on sparse subsurface control, depicted a possible position of the Sabine River trench several miles east of Johnsons Bayou with the top of the Pleistocene (Prairie) at a minimum depth of 124 feet below sea level at the shoreline. He also showed a Sabine or Neches river trench in the area of Sabine Pass with the top of the Pleistocene at a minimum depth of 220 feet below sea level at the shoreline. Later, Fisk and McFarlan (6) mapped a Sabine trench which bifurcated approximately 30 miles offshore in the Gulf of Mexico, with the right fork located in almost the same geographic position as his previous Sabine trench. He defined a second trench as the Neches trench, with part of it passing through the mouth of Sabine Pass and then through the western extension of Cameron Parish, Louisiana, between Blue Buck Point and Johnsons Bayou, across Sabine

Lake to connect with the mouth of the Neches River. He delineated both trenches with the 100-foot contour, postulating a possibly greater depth of entrenchment.

Historical Development of Late Quaternary Geology

The terraces and later deposits can be ascribed to alternate valley-cutting and filling resulting from fluctuations of sea level. These fluctuations were caused by the waxing and waning of the continental ice sheets during the Quaternary period. During the waxing stage of the glacial sheets, sea level was lowered, stream gradients were increased, and the streams cut vigorously into the underlying deposits; this was the valley-cutting stage. Also during this interval, streams were capable of transporting coarser-grained materials. As the ice sheet melted (interglacial stage), sea level rose, causing a diminution of stream gradient and consequent valley-filling. Coarse sediments grading upward into fine-grained sediments were deposited during this stage. The general sequence of the fluviatile deposits is:

Top substratum—fine sands, silts, and clays;

Basal substratum—gravels and coarse sands.

This depositional sequence grades coastwise into a thicker deltaic sequence where, generally, clays and silts are more common and overlie gravelly sands.

Upon completion of each cut-and-fill cycle, the coastwise portions of the depositional surfaces subsided, and the resulting isostatic adjustment uplifted and steepened the interior sections to preserve them in their present-day position and sequence. The oldest surface, Williana (exposed beyond the limits of the study area), occurs at a higher elevation and has a steeper gradient than the next younger surface, and so on, with the Prairie and Recent surfaces generally showing the least amount of deformation, or none at all.

Approximately 25,000 years ago (12), with the retreat of Late Wisconsin ice, sea level began to rise, marking the beginning of the Recent epoch. Sea level continued to rise, with a probable minor fluctuation in the early Recent (Mankato (?) glacial substage), until about 5,000 years ago[3] when the sea reached its present level. Apparently, no major changes in sea level have occurred in the last 5,000 years (12).

With the last advance of the sea, the coasts and associated stream valleys were drowned to form bays as well as estuaries such as Sabine Lake. The rise in sea level decreased stream gradients and caused alluviation of the valleys.

Since the maximum inland stand of the Gulf which is marked approximately by the cheniers farthest inland, the coastal region around Sabine Pass has generally been built out into the Gulf of Mexico. The record of progradation is interpreted from the features of the chenier plain, such as the stranded sand and shell ridges along the marsh and mudflat deposits separating the ridges (see fig. 1). Howe and others

3. The 5,000-year estimate for the beginning of the stillstand of the Gulf of Mexico is questioned by Gould and McFarlan (1959).

(10), Fisk (4, 5), and Van Lopik (15) offer excellent descriptions and interpretations of the cheniers along the Louisiana coast.

Alluviation from the rivers has resulted in the filling of the entrenched valley of the Neches and Sabine rivers. This valley-filling and the prograding of the shoreline have closed the southern segment of the valley and have formed the modern Sabine Lake with its tidal outlet, Sabine Pass.

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Origin of the Mitchell Plain in South-Central Indiana[1]

Richard L. Powell, Indiana Geological Survey

The pre-karst surface of the southern part of the Mitchell Plain was leveled by surface streams of late Tertiary age that headed on the plain or within the Norman Upland and flowed through re-entrant valleys in the Crawford Upland into the pre-Pleistocene Ohio River. The karst features and subterranean drainage characteristic of the Mitchell Plain developed as a lower base level was established by rejuvenation during the late Tertiary or early Pleistocene.

These ancient stream routes were first noticed on the Corydon West, Depauw, Fredericksburg, Hardinsburg, Leavenworth, Mauckport, Milltown, and New Amsterdam topographic quadrangles, which cover part of the Mitchell Plain and the Crawford Upland. The ancient stream courses are represented by three kinds of topographic features which are well shown on these maps: hanging dry valleys, bedrock terraces, and abandoned meander loops. The topographic features were checked on aerial photographs and in the field to determine their geologic characteristics.

The fossil drainage system studied occupies part of the present drainage basins of Blue River, Indian Creek, and Buck Creek, which are tributaries of the Ohio River (fig. 1). This combined drainage area includes approximately 900 square miles mostly in Crawford, Harrison, and Washington Counties. This drainage basin includes parts of three physiographic units: the Norman Upland, the Mitchell Plain, and the Crawford Upland (2). The Norman Upland is upheld by resistant shales and siltstones of early Mississippian age, which form an eastward facing cuesta that is called the Knobstone Escarpment. These rocks dip westward about 30 feet to the mile and pass beneath the Mitchell Plain. The upper surface of these nonsoluble rocks is the ultimate base level of karst development in the Mitchell Plain.

Figure 1. Map of south-central Indiana showing the location of drainage features.

The Mitchell Plain is a karst plain that has formed by solution of a thick series of limestones of middle Mississippian age. In general, the plain is streamless and appears low and rolling, but it is transected by three master streams, the two forks of White River and the Ohio River, in meandering valleys that are entrenched about 250 feet into the karst plain. Those surface tributaries to these master streams that head within the Mitchell Plain or in the Norman Upland just west of the Knobstone Escarpment also have deeply entrenched meanders within the lower reaches of their valleys. For example, the lower courses of Blue River, Indian Creek, and Buck Creek lie about 100 feet below the Mitchell Plain and about 300 feet below the summits which have been considered as remnants of an older peneplain or erosion level (fig. 2).

1. Published with permission of the State Geologist, Indiana Department of Conservation, Geological Survey.

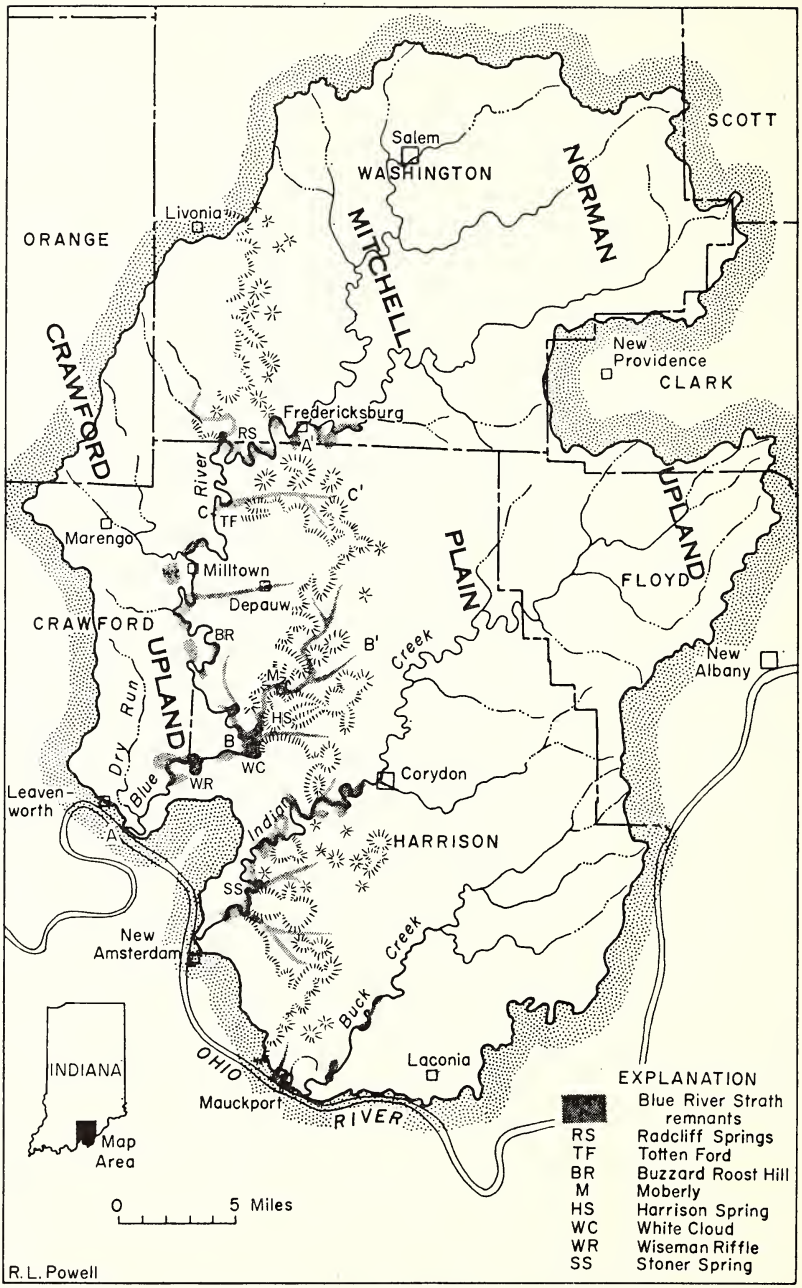

Figure 1. Map of south-central Indiana showing the location of drainage features.

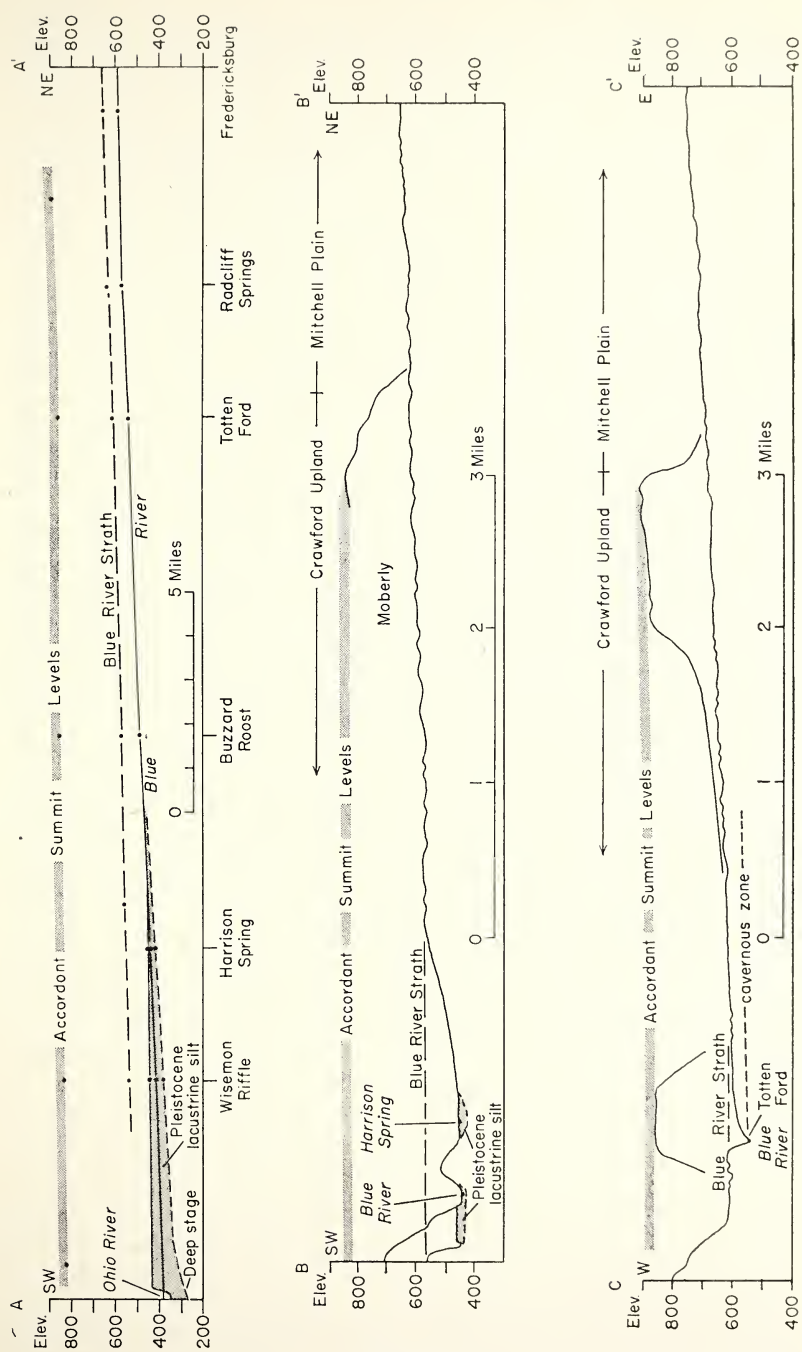

Figure 2

A. Generalized profile showing the character of the Blue River Strath between Fredericksburg and the Ohio River.
B. Profile of the strath extending from Harrison Spring to the Mitchell Plain.
C. Profile of the strath extending from Totten Ford to the Mitchell Plain.

The Crawford Upland is a rugged hilly area developed on alternating sandstones, shales, and limestones of late Mississippian age. These rocks, which overlie the limestones of middle Mississippian age of the Mitchell Plain, are also present in eastern outliers of the Crawford Upland which break up the low, rolling topography of the plain. The middle Mississippian limestones crop out along the valley walls of all the larger streams that lie within the Crawford Upland in the Blue River and Indian Creek drainage basins. For this reason, some of the subterranean drainage heading on the Mitchell Plain flows down the dip of the rocks to resurface along streams in the Crawford Upland.

Blue River enters the Crawford Upland along the Harrison-Washington county line and meanders 55 miles to the Ohio River near Leavenworth, a straight-line distance of approximately 19 miles. Indian Creek within the Crawford Upland meanders 19 miles to travel 8 miles straight-line distance. In addition to the present-day meanders, there are abandoned meanders and associated meander cores which indicate that the route was longer in the past than at present. There are also several abandoned meanders along Buck Creek, which flows entirely within the Mitchell Plain. The prominent alluviated meander at the mouth of Buck Creek (fig. 1) may have been formed by the Ohio River during an earlier erosion cycle. The Ohio River does not exhibit the tight meander pattern of Blue River and Indian Creek, but like these streams, its valley is wider within the Mitchell Plain than in the Crawford Upland.

The meandering pattern of these streams was probably inherited from streams of an older erosion cycle established at a higher level. The primary evidence of a drainage system established at a base level higher than the present one is a group of accordant terraces, abandoned meander loops, and hanging valleys 70 to 130 feet above the present streams. The strath remnants are characteristically small karst plains covered with varying thicknesses of terra rossa and loess. Stream-borne iron-stained pebbles, angular chert fragments, and subrounded geode fragments are found in small patches or as scattered pieces. All these erosion-level remnants are accordant in grade from the mouths of Blue River and Indian Creek to the Mitchell Plain.

The accordant karsted strath terraces along Blue River are here named the Blue River Strath (fig. 2A). The bedrock terrace within the meander core (sec. 26, T. 3 S., R. 2 E., Leavenworth Quadrangle) at Wiseman Riffle lies approximately 130 feet above Blue River. The abandoned valley containing Moberly and ending north of Harrison Spring lies about 110 feet above Blue River (NE¼ sec. 18, T. 3 S., R. 3 E., Depauw Quadrangle). This valley extends eastward onto the Mitchell Plain (fig. 2B). Southwest of Buzzard Roost Hill (secs. 34 and 35, T. 2 S., R. 2 E., and secs. 2 and 3 T. 3 S., R. 2 E., Milltown Quadrangle) the karsted bedrock terrace representing the Blue River Strath covers an area of half a square mile and lies about 90 feet above Blue River. The Blue River Strath is about 65 feet above Blue River at Totten Ford Bridge, where an abandoned karsted valley extends eastward onto the Mitchell Plain (fig. 2C). A bedrock terrace (NE¼ sec. 24, T. 1 S., R. 2 E., Fredericksburg Quadrangle) just east of Radcliff Springs lies about 60 feet above Blue River. The differences in elevation

indicate that the Blue River Strath has an accordant level with a slighter grade than that of the present Blue River. Except for a few places where either cutoffs or diversion has occurred, Blue River now flows in a valley within the valley of the Blue River Strath.

Valleys that extend eastward from Blue River and Indian Creek through the Crawford Upland into the Mitchell Plain and that do not now contain a through-flowing surface stream are former tributaries which have lost their surface waters to subterranean channels. The valley floors contain numerous sinkholes and a cover of terra rossa and loess but do not contain prominent dry beds to serve as temporary surface routes for floodwaters. The waters which divert to underground routes along the valleys appear to resurface near the ends of the valleys along Blue River or Indian Creek, as karst springs, for example, Harrison Spring or Stoner Spring (fig. 1). These springs tend to be located near the base of the hanging valley and along the updip side of a meander loop. Karst springs are also situated at the termini of several hanging valleys which do not extend headward onto the Mitchell Plain, but which rather head along the east margin of the Crawford Upland.

Profiles constructed along the valleys show the pre-karst drainage level and the gradient of the valley (fig. 2). The elevations of the downstream ends of the hanging valleys are comparable to those of strath terraces along Blue River or Indiana Creek near the end of the valley. The gradients of the straths in the lower part of the valley are similar to those of the Blue River Strath, but they become steeper towards and within the Mitchell Plain. This steepening indicates the headwaters of the former drainage basin. The drainage basins of the karsted valleys extended onto the Mitchell Plain, where they adjoined each other or the drainage areas of Blue River, Indian Creek, or Buck Creek, which were established at similar levels. The character of the gradients of the Blue River Strath and some of the abandoned valleys is shown on the profiles.

The Blue River Strath and equivalent strath terraces along Indian Creek and Buck Creek represent the stream system which downcut part of the Mitchell Plain to its pre-karst surface. This stream system consisted of three large streams, Blue River, Indian Creek, and an Ohio River comparable in size to the present Blue River, and five or more small streams which had eroded headward through the Crawford Upland onto the Mitchell Plain. The planation of the limestone bedrock was most likely by both subaerial and subterranean erosional processes.

There are some caverns which formed at elevations higher than the Blue River Strath in the Crawford Upland and in some of its outliers on the Mitchell Plain. Several of these, notably Pitman's Cave, Ragain's Cave and Howard's Cave (3) lie slightly above the level of the Mitchell Plain but were probably developed at grade with the Blue River Strath. The karst features on the remnant surface of the Blue River Strath and on accordant parts of the Mitchell Plain have developed at grade with a base level lower and younger than that of the strath. This new base level enabled surface waters to descend joints and flow laterally at the water table along bedding planes in the limestone, generally downdip, to surface outlets along the major entrenched streams.

The Blue River Strath is at least 200 feet below and is therefore younger than the erosion level of the Lexington or Highland Rim Peneplain which existed during the early Tertiary. The loess which covers the Blue River Strath is probably of Pleistocene age, and the strath lies considerably higher than Pleistocene erosion levels thus far described, particularly the maximum downcutting of early Pleistocene age called the "deep stage" (4) (fig. 2A). Thus the strath is probably pre-Kansan, perhaps pre-Nebraskan in age. If the age assignments of other erosion levels and events are correct, the Blue River Strath must represent a latest Tertiary or earliest Pleistocene drainage system. The strath appears to represent a base level that was of regional significance in the Mitchell Plain and its correlative Pennyroyal Plain of Kentucky. It occupies a position similar to that of the Parker Strath, which has been described as part of the preglacial drainage of the Teays in Ohio and West Virginia (1) and in northern Indiana (4).

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Degree Days in Indiana

BENJAMIN MOULTON, Indiana State College

Several sources reveal some general aspect of degree days in Indiana, but none utilize statistics available in recent years as more stations submitted information on which more detailed work could be based. This study is part of a continuing interest in degree day factors in the hopes that its fuller meaning will eventually end in a more definitive value, an ecological implication, or an engineering value more worthy of use. In this study, deviations and extremes are emphasized as well as means.

In this study, 49 stations showed sufficiently continuous records to warrant their inclusion. Approximately another hundred stations had inadequate records and were used as supporting sources but not conclusive sources of information. A number of maps were prepared to show the distribution of degree days; by month, by season, and for the year.

Annual Degree Days

From north to south the average annual degree day average is about 2600. As one might expect, stations in the northern tier of counties experience up to about 6400 degree days and the southern tier about 3800 degree days. Isolines of 500 degree days are fairly evenly spaced until the southern third of the state where changes occur more rapidly.

A close view reveals that degree values can change rapidly within short distances although this fact doesn't show up on the map. The difference in annual averages between Evansville and Evansville airport is about 500. A similar situation prevails in the Indianapolis station and the airport nearby. Porter County has a pattern also which reveals a marked difference between a littoral station and an inland station.

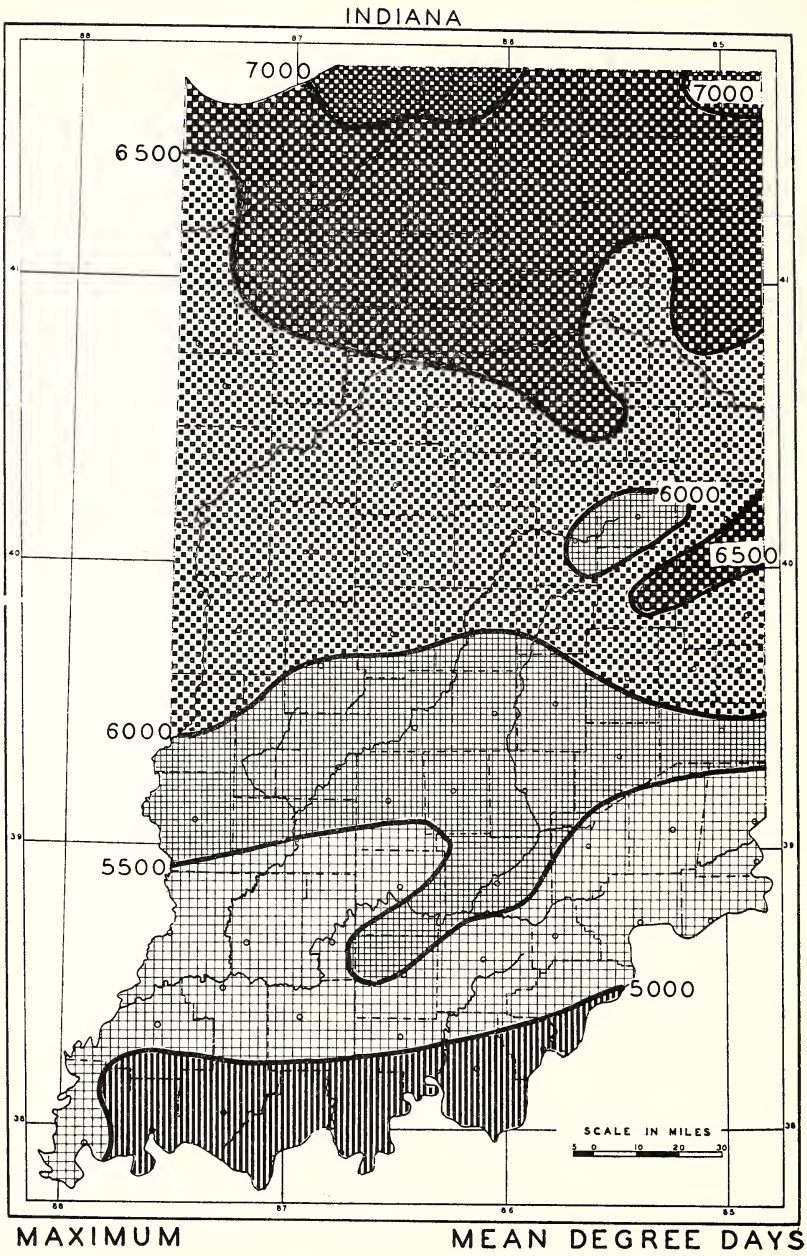
A map (map I.) showing maximum record occurrences reveals around 7000 in the north and 5000 in the south. This generally represents about 1000 more degree days than average for most stations. Although this is a flexible figure in actual degree days, percentagewise it is far more uniform. Even in closely related stations the percentage remains nearly constant or about ten per cent.

When minimum records were examined, it was found that the differences between average conditions and minimum were about 500 to 800 degree days. The deviations were not as great in the north as in the south.

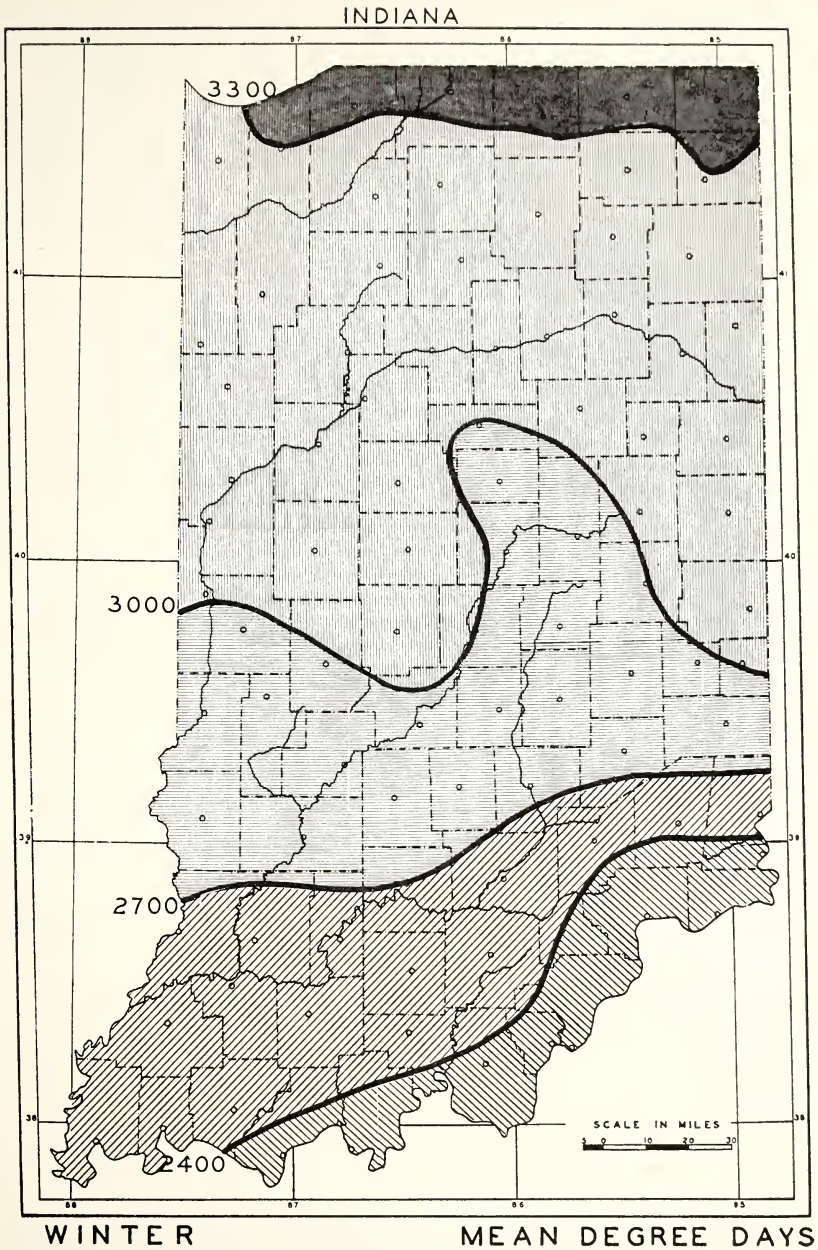
Heating engineers generally recommend the use of electricity for heating homes when about 5000 degree days or less are experienced. If this is true, then a large share of Indiana is not in the preferred electric heating belt.

Seasonal Distribution of Degree Days as Shown by Map II

Winter patterns are illustrated because about 60% of the degree days occur in winter months. Percentages reveal more degree days in the southern portion than in the northern portion. The extreme of 3300


INDIANA
7000
7000
6500
6000
6500
6000
5500
5000
SCALE IN MILES
5 0 10 20 30
MAXIMUM
MEAN DEGREE DAYS

Map 1


INDIANA
3300
3000
2700
2400
SCALE IN MILES
WINTER MEAN DEGREE DAYS

Map 2

is found in the north but about 2400 in the southern stations. Isolines indicate uniform change from north to south but as on previous observations, the change takes place more rapidly in the south.

Spring has about 300 more degree days than fall and about 25% of the total of the year. This varies from about 22% in the north to about 35% in the south. There are about 1500 degree days in Spring in the north and about 900 in the south. One comment here should note the relationship between stations on Lake Michigan shores and inland stations. The Spring records imply a continuation of cold influences to increase the degree day accumulation but at all other seasons, the littoral location seems to create a reduction in degree days.

Fall ranks as the third season in total number of degree days. About 1200 in the north and about 900 in the south. It is the most uniform over the state. The values are relatively even. One interesting point is nearly all the stations are uniformly close to 900 with the exception of Jeffersonville with a total of 674 degree days.

Summer has few degree days but no station of the 49 has absolutely none.

Monthly Distribution of Degree Days

Most statistical summaries of degree days, such as that put out by the American Petroleum Institute, generally ignore the warm months. Therefore, this study does not include the maps for June, July and August, although the statistics for the three months are included in the annual averages.

September has few degree days, and they vary from 25 in the south to slightly more than 100 in the north. Stations along Lake Michigan have less than inland surrounding stations. Several stations in the central part of the state had above average amounts for the region.

October has from 200 to 300 degree days. The state-wide picture is uniformity, however. Evansville had 199 and Waterloo 377, but changes were not abrupt from one area to another.

November finds greater contrast and with a low of 542 to a high of 788. Changes are not abrupt. Lake stations show up well and the isolines are well distributed.

December is the second coldest month as represented by degree days. The lake still is a reducing factor. Between a lake station and a station a few miles inland is 50 to 150 degree days. Jeffersonville has 789 and South Bend 1116. Nearly two-thirds of the state experiences about 1000 degree days.

January is the coldest month. Jeffersonville experiences 868 and there are 1237 in South Bend. The largest share of the state experiences between 1100 and 1200.

February is the third coldest month and is only slightly warmer than December. Most stations run about 100 degree days less than December and 200 less than January. Most of the area of the state records between 800 and 1000 degree days.

A warming trend goes on slowly and March is slightly warmer than February. The lake influence is gone. Evansville records 573 and

South Bend 946. Most of the state has less than 700 degree days. Most stations have a hundred less than February.

April warms up rapidly. The number is about half that of March. Evansville is down to 219 and South Bend 492. Most of the state has between 300 and 500 degree days.

May is the last month analyzed. Northern stations have slightly over 200 and most southern stations have between 50 and 100. The transition from north to south is gradual.

Summary

Although the statistics used are of short duration, they are complete within the period. The probability is that the pattern of distribution is well established and only the quantity might change with further work.

The persistent problem of region generalization versus microclimates constantly appears. It would seem that for any precise reason that the individual station nearest would reveal the essential deviations that have to be known if the application of degree day information is to be worthwhile. The three stations utilized by the American Petroleum Industry reveal little value except for the three stations. If the total degree days are to be utilized in determining fuel costs, state-wide generalizations are of little value.

Intriguing, but unanswered is the paradox of December being the second coldest month but Spring the second coldest season.

Degree day variabilities increase from north to south and especially in winter.

Valley, shore and suburban locations show marked contrasts to their opposites.

As we proceed southward, the percentage of degree days in the winter months increases. Like other state pictures as a whole, Fall and Spring quantities decrease but remains in their relative position for the entire year.

The Residence Pattern of the Instructional Staff at Indiana University During the Twentieth Century: In City of Bloomington, Indiana

BERNARD W. RILEY, Indiana University

Introduction

Bloomington, as a college campus city, may be taken as a convenient microcosm of urban growth and development, both within and without the city limits, where a substantial proportion of the alienation of formerly rural land has been used for institutional purposes rather than purely commercial or industrial use.

Concomitantly with the growth of the institution proper (the University), the expansion of those persons associated with the functions and duties of the college (the Staff) has also occurred.

For the purposes of this study it is hypothesized that the Instructional Staff of the University represents the intellecual section of the Bloomington Community. If these persons may be regarded as a representative body, it is suggested that the pattern of their residence will provide significant illumination to the changing pattern of Bloomington City residence during the decades of the present century, throughout which period the presence of the University has been a constant phenomenon, of the urban population at the Monroe County seat.

Such a residence pattern, it is further postulated, may indicate the areas which are considered to be residentially "*desirable*,"[1] both currently and during the years when the inevitable changes, both wrought by the expansion itself and the accompanying socio-economic changes, occurred as the result of this concentration in Bloomington City of the major State Institution of higher education for the Hoosier population.

These changes will be examined statistically and cartographically for changes in the areal proportions in the sectors of the city adjacent to the University.

The Problem

The study is concerned with the growth and geographical distribution of the residences of Instructional Staff of Indiana University, for four index years, at twenty year intervals; namely 1902; 1922; 1942; 1962.

This distribution pattern when plotted on a base map is to be examined for possible answers to two questions. (1) Has the pattern of Instructional Staff residence shown any significant migration or density change within sectors of the city? (2) Is there any evidence of significant clustering in "desirable" areas?

1. "Desirable" here is meant to imply residence areas of convenience and conviviality to those persons employed as instructors at the University by reason of their intellectual capacity.

Method of Approach

The study was prepared in the following manner. Firstly, a base map was prepared showing the major reference points which have not significantly altered, and have been a limiting boundary to residence, throughout the sixty year period. These are:—(1) Main highway routes of State Road 37 (N/S) which are College and Walnut avenues through Bloomington City at the present time. (2) State Roads 45 and 46 East, to Unionville and Nashville respectively, between which, as East 10th Street and East Third Street within the city limits, the main boundary of the Indiana University Campus is contained. (3) The Monroe County Courthouse Square, situated between College Avenue (west) and Walnut Avenue (east); Sixth Street (north) and Kirkwood Avenue (or Fifth Street; south). The south-east corner of this block is the intersection of the sectors of the city; NW: NE: SE: SW.

Secondly, a list of Instructional Staff residential addresses was obtained from the Office of the Registrar, Administration Department; Indiana University, for the four index years, 1902; 1922; 1942; 1962.[2] The addresses where precisely given were located on the base map, being shown by dot-distribution. For each distribution a centre of gravity was calculated and marked on the map. The existing campus for each of the index years is marked, as far as could be accurately ascertained (1) within the 1962 main campus outline.

Limitations of the Study

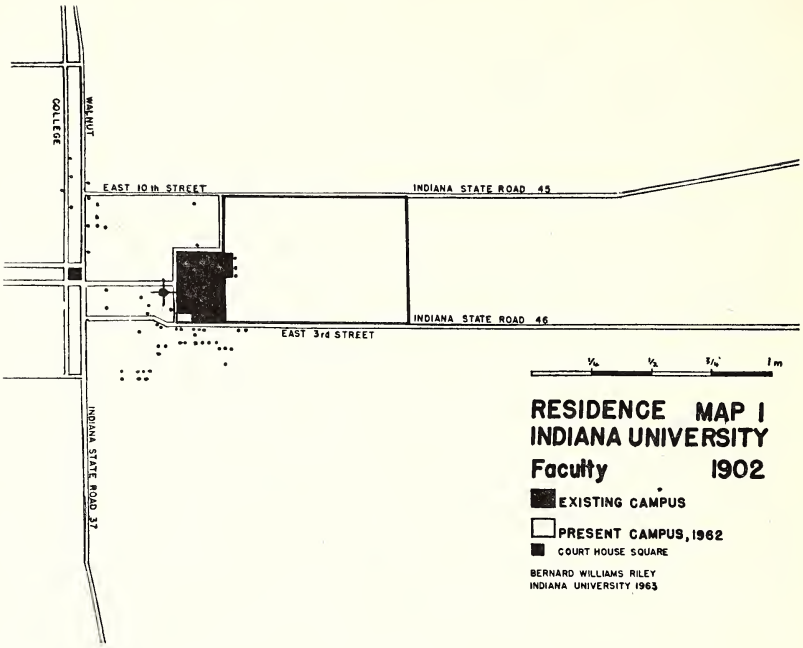
Only those addresses in the list which could be accurately plotted were used. Deletions from the lists are statistically accounted for (Table I). Expansion of Instructional Staff has only been accounted for as percentages above the datum year of 1902, in the statistical appendix. This project may be regarded as a pilot study only, and should be treated as indicating a distribution pattern as if from four static frames of a continuously moving picture of an on-going process, as the Instructional Staff not only expands but also changes its internal composition. No attempt has been made to show ranking within the Staff Lists, according to professional status such as "full," "associate" or "assistant" professorship; nor has any attention been given to residential anchoring which tenure of office might induce or influence. In this respect, opportunity for further refinement of the patterns according to some system of rank obviously suggests itself.

The Findings

1. The Pattern of Distribution 1902 (Map 1)

In 1902, the existing campus lay between Third and Seventh streets, Indiana Avenue on the west and Sluss (or Woodlawn) on the east. The property at the southwest corner of the campus, at the south end of the present Law Building was not included. The total acreage was 50.8 Acres (1). The faculty residence pattern still showed the influence of the former siting of the proto-university on North College Avenue, and

2. The author would like to acknowledge, with grateful appreciation, the efficient and prompt help he received from Mr. M. Devon Scherer, Associate Registrar, in obtaining these records.



Map 1

indeed the incumbent President of the day, William Lowe Bryan resided at 812 North College Avenue, the official residence. However, the pattern illustrated by the map shows the development of two clusters. Firstly, the cluster of older residences north of Kirkwood between College and Lincoln Avenues. Secondly, a cluster along the southern margin of the campus aligned along the southern side of Third Street, and north of Second Street, in Atwater and Hunter streets, and Smith Street west of Henderson.

By city sector, the statistical breakdown is given below (Table I). Even by 1902, the SE sector had begun to show dominance over the others. The NE sector, due to the lingering influence of the former college site showed second place. The centre of gravity of this population lay in the SE sector at the SW corner of the block bounded by East Fourth, East Kirkwood, South Indiana and South Dunn.

2. The Pattern of Distribution 1922 (Map 2)

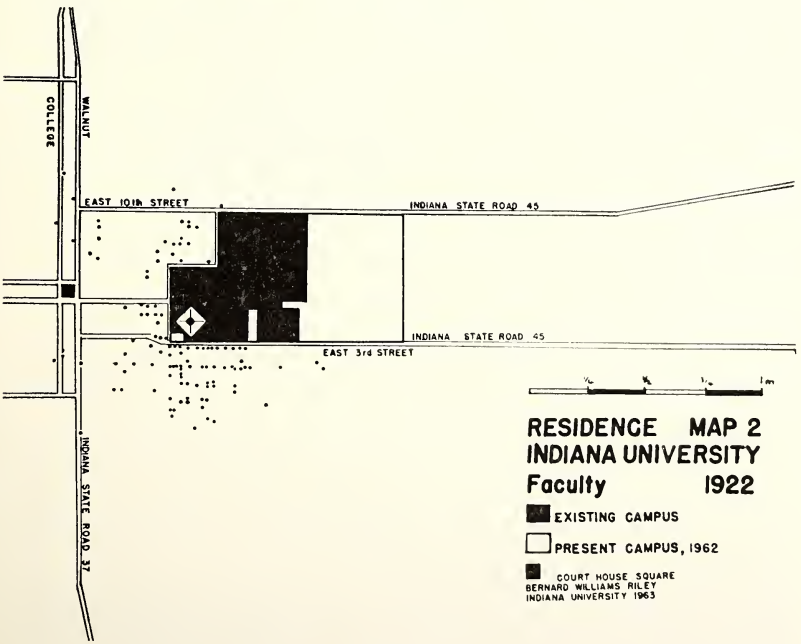
The existing campus had extended to approximately half of the present (1962) extent and now had an eastward extension to include the "old" fieldhouse and gymnasium and the "old" stadium. The total was now 126.5 Acres (1). The Instructional Staff had more than doubled in the interval. The residence distribution shows a considerable shift eastward and a concentration along the southern margin of the main instructional area, clustering in a linear fashion along the streets immediately south and parallel to East Third Street, along Atwater,

TABLE I

Statistical Appendix of Data
Indiana University Instructional Staff

Year	1902		1922		1942		1962	
	No	%	No	% Inc.	No	% Inc.	No	% Inc.
Faculty	67	—	172	256.7	316	471.6	1,295	1,932.8
Addresses Plottable	60		134	223.3	261	435.0	956	1,593.3
% Plottable	89.5			77.9		82.6		73.8
Quadrants								
NE.	14	23.33	26	19.40	65	24.90	332	34.72
SE.	40	66.66	102	76.11	192	73.56	555	58.05
SW.	2	3.33	2	1.49	1	0.38	(1*)4	0.41
NW.	4	6.66	4	2.98	3	1.14	(3*)9	0.94
Total	60	99.98	134	99.98	261	99.98	900	94.12
							(56#)	5.88

* Figures in brackets are those shown on the (Map 4).
\# Balance, 56, live outside the city boundary beyond the area of the map, i.e., those who are resident in nonincorporated areas beyond the margins of Map 4.

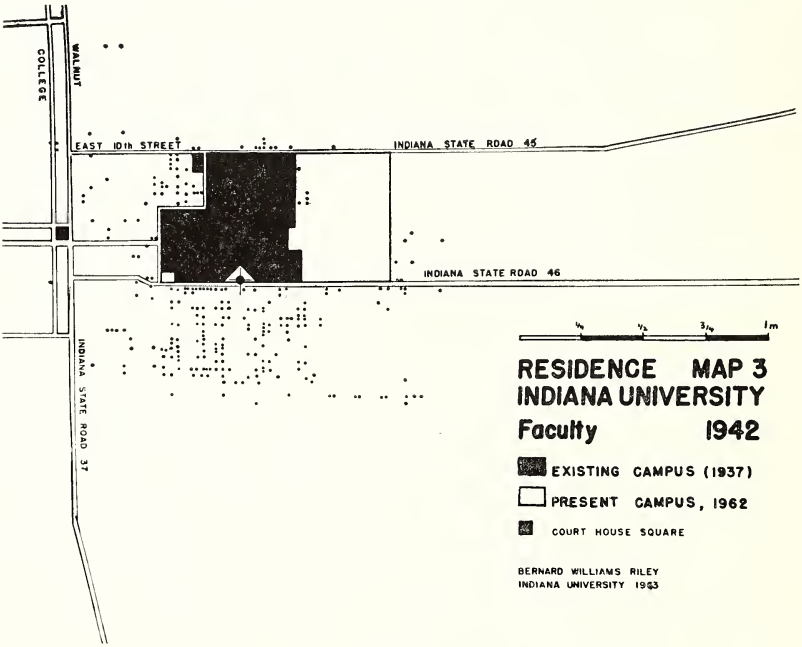


Map 2

Hunter, Smith streets. There had been a 10% increase in the SE sector. By comparison, the NE sector had already begun to show a decline, a drop of some 4% and showed a clustering considerably to the east of the 1902 grouping, which was located now between Grant and Woodlawn instead of closer to College and Walnut avenues. The centre of gravity of the population now lay inside the campus boundary near the SW corner, approximately in the wooded hollow bounded by the Law Building, Swain and Lindley Halls.

3. Pattern of Distribution 1942 (Map 3)

The existing campus shown on the map is that actually for 1937, but the bounds of the institutional buildings were substantially the



Map 3

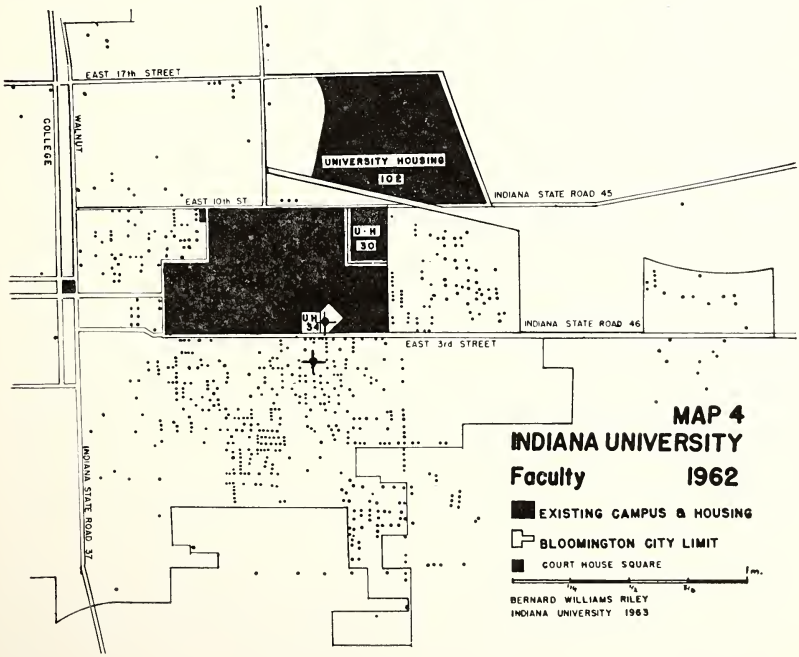
same as that for 1942; "temporary" teaching huts were inserted between the major buildings (where some may still be seen in evidence today) during the wartime emergency (1).

East of the main instructional area, the housing which was built during the emergency did not accommodate any of the instructional faculty. This includes the area now Trees Centre and the recently demolished buildings of the Rogers Centre where the Graduate Residence Centre now stands. However, the SW corner of the campus was squared off, and extended eastward to Jordan Avenue, where the University High School marked the limit of the extent. The instructional Staff had almost doubled from the 1922 figure and quadrupled from that at the turn of the century (1902). Instructors residence pattern shows

that there was a considerable southward extension perpendicular to the southern campus margin, as far south as Maxwell Lane. The residences were still predominantly aligned along the W/E streets, though the fill-in showed alignment along the N/S streets of Fees, Woodlawn, Hawthorne and Jordan. Although the residence in this area rose by 90 persons, proportionately this amounted to a decrease within the sector. This was due to an increase in the NE sector of an absolute value of 39 persons, 13 in excess of the total 1922 population, and hence shows the greater proportional increase. In the SW and NW sectors the residence totals had so decreased, absolutely and proportionally, to become statistically insignificant. In addition, from 1924, 812 North College Avenue ceased to be the official Presidential Residence, when Dr. William Lowe Bryan moved to the present residence within the campus bounds. The centre of gravity of the population now lay just inside the southern boundary of the campus on the north side of Third Street, at the entrance opposite Faculty Avenue.

4. The Pattern of Distribution 1962 (Map 4)

The map has been drawn with the Bloomington City Limit added. This has been done to show the rather arbitrary boundary in the SE



Map 4

sector of the City, between residential subdivisions that have been included or excluded from the city proper, although the reasons for these discrepancies are beyond the scope of this paper. For full appreciation

of the present pattern of residence of the Instructional Staff, the following salient facts must be borne in mind, which are new vectors in the main in that these were not operative on the former distribution patterns. These are:—

1. University housing for both students and junior faculty members, is a large scale feature of the extended campus, which had not operated hitherto within the residence pattern. North of East Tenth Street and the Illinois Central Railroad, and east of North Jordan Avenue, married housing quarters and Graduate Residence Centre have been established by the University.

2. After the second World War, the extension of urban subdivisions south and east of Bloomington City occurred, especially along Indiana State Road 46, eastward to Nashville. Here the subdivisions were in closer contact with the commercial heart of the city without having to traverse any of the earlier industrial development.

3. The increased mobility of the population as a whole has meant that "desirable" residence is not any longer within an accessible walking distance of the instructional section of the campus.

4. University owned dwelling property, where occupation by any faculty member is subject to a three year rule. This will tend to perpetuate an address, for University personnel, while the tenancy obviously remains fluid.

Nevertheless, the pattern of residence of the population studied still shows the concentration of the SE sector adjacent to the University main campus. Within this SE sector at least three sub-clusters can be demonstrated. Firstly, a cluster aligned along south Hawthorne, Ballantine, Highland, Jordan and Swain, in the 300 and 400 blocks of each. Secondly, a cluster within Maxwell Manors Subdivision, east of Bryan Park and between First and Davis streets. Thirdly, a clustering west of South High Street in the Longwood, Manor Wood and South High additions.

Referring to the statistical appendix, these statistics are somewhat misleading. Of the total NE sector population of 332, University housing accounts for 140 (Married housing, 102; Graduate Residence Centre, 30; Campus Club, 5; Union Building, 3). This would have the effect of decreasing by 14.6% the NE sector population to only 20.0%. Similarly, subtracting the residence population in University Apartments West and East (totaling 34) reduces the SE sector from 58.0%, to 54.5%, a drop of only 3.5%. Thus the effect of the University-tied housing is to mask the full effect of the differential between the sectors. For this reason two centres of gravity have been plotted on the map, one for independent housing residence, as far as it is possible to tell from residential address alone; the second centre of gravity includes the University housing. These are located respectively at—a) For *independent Housing*, a centre of gravity at Swain Avenue, between Hunter and Atwater. b) For *University-housing Inclusive*, at Mitchell Avenue, half a block north of the southern campus perimeter. Thus it can be seen that the effect of the University housing is to draw the centre of gravity of the population one block to the east and two to the north.

Conclusions

A study of the four index year maps and the statistical table reveals the following conclusions.

1. The growth of the Instructional Staff increased at an increasing rate in the twenty year periods. The greatest growth was from 1942-1962, when the increase was over four times the 1942 total.

2. The post war provision of large scale accommodations for the Instructional Staff has not greatly affected the pattern of residential distribution with regard to the SE sector of the City.

3. The most significant residential area for the independently-housed Instructional Staff throughout the whole sixty year period has been the SE sector and has always accounted for over half this population.

4. The NE sector of the City has seen the greatest increase in University controlled housing. Were it not for this fact the real increase of the SE sector would not be statistically masked.

5. The centre of gravity of the University Instructional Staff residence pattern has migrated steadily eastward from the western border of the main instructional campus area in 1902 to its present position over halfway along the southern border of the campus a distance of some fourteen blocks.

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Land Use of Selected Cities in Indiana

LEE GUERNSEY, Indiana State College

Introduction

This is a paper which is based upon some land use data gathered from field research in six Indiana cities. The first part of this paper is a brief description of the technique and classification system used to map urban land uses. The second part is a brief examination of some land use data of six Indiana cities which is then compared with the functional classifications of these cities.

Mapping Technique and Classification System

All land included in this study was classified as developed or vacant or water areas in accordance with the Bartholomew method of classifying urban land uses (1). The developed land includes all areas used for urban functions whether open use such as parks or intensive uses, such as downtown department stores. Land not used for urban functions, such as cropland or undeveloped land for subdivisions, was classified as vacant.

The field mapping was conducted by a team of two, mapping from inside an automobile and plotting the symbols on an acetate overlay above an existing Sandborn Atlas base map of that city. This "windshield mapping procedure" was carried out by undergraduate students who were majoring or minoring in geography at Indiana State College. At the end of each work day in the field, the data from the overlays were plotted on a large-scale base map in the office. The base map, normally drawn from the city engineers base map, showed all streets and lot lines for all developed areas of the city. The existing land use for each lot was plotted on the large line map according to Bartholomew's land use classification system (1). Letters were used as symbols of land use in the field, but the final maps were reproduced in multicolors.

The statistical summaries are prepared in terms of acreage consumed in each category of use employed in the survey (Table I). Percentage summaries are then used to compare the city with the Bartholomew percentages of cities of comparable size which is termed the "Percentage of Standard Land Usage" (Table II).

The actual measuring of land use acreages was done by a planimeter or an areagraph. The accuracy of areagraphs used vary from 90 per cent to 97 per cent. The choice of the areagraph or the planimeter was determined by the dissemination and areal extent of a common land use.

With this simple, standardized system and technique employed in the six cities, and with the same persons mapping and measuring the land use of these cities, selected characteristics, comparisons and contrasts will be made.

TABLE I

COMPARATIVE LAND USES

Percentage of Total Developed Land

City	1960 Population	Residential	Commercial	Transportation, Utilities, and Communication	Industrial	Community Facilities
Jeffersonville	19,522	43.6	5.4	27.6	13.3	10.1
Logansport	21,106	40.8	4.5	30.0	6.4	18.3
LaPorte	21,157	39.9	3.9	34.1	11.2	10.9
Bloomington	31,357	35.9	2.9	16.6	14.8	29.8
Mishawaka	33,361	46.1	4.0	35.5	7.7	6.7
Marion	37,854	32.0	4.5	41.7	9.2	12.6
Bartholomew Standard*	—50,000	39.6	3.1	33.3	5.7	18.3

* Based upon 28 United States cities of less than 50,000 persons by Harland Bartholomew, *Land Uses in American Cities.* Harvard University Press, 1955. pp. 21-73.

TABLE II

PERCENTAGE OF STANDARD LAND USAGE

City	Residential	Commercial	Transportation, Utilities, and Communication	Industrial	Community Facilities	Functional Classification**
Jeffersonville	110	174	83	233	55	Industrial
Logansport	103	145	90	112	100	Industrial and Transportation
LaPorte	101	126	102	196	60	Industrial
Bloomington	91	94	50	260	163	Professional
Mishawaka	116	129	107	135	37	Industrial
Marion	81	145	125	161	69	Diversified
Bartholomew Standard	100	100	100	100	100	

** Based upon Howard J. Nelson's criteria included in "A Service Classification of American Cities." *Economic Geography,* July, 1955. pp. 189-210. Employment Data based upon 1960 Indiana Employment Security Division Reports.

Land Use Characteristics

From Table I comparative land uses of the six cities and the Bartholomew standard can be analyzed. Table II reveals a comparison of the percentages of standard land usage, and provides data for a comparison of the existing land use and their functional classifications based on 1960 employment data and the use of Nelson's criteria.

The six cities are distributed in a random fashion within Indiana and no attempt is made here to analyze their many local geographical differences. The cities are third and fourth class cities which range in population from 19,522 persons in Jeffersonville to 37,854 persons in Marion. The 28 cities of less than 50,000 persons, which were selected by Harland Bartholomew and Associates, were used to quantitatively compare the land use characteristics of the six Indiana cities.

Jeffersonville, with 5.4 per cent of the total developed land in commercial uses, has relatively more developed commercial land than any of the six selected cities (Table I). Jeffersonville has 174 per cent of standard commercial land usage, and the areas consumed for industry in Jeffersonville is 233 per cent of the average of the 28 selected cities. This unusually large area is due largely to the extensive area in the Quartermaster Depot. In contrast, only 83 per cent as much land is consumed for transportation, utilities, and communication and only 55 per cent of the land in community facilities as in the Bartholomew Standard (Table II). As can be also read (Table II), the residential areas consume 110 per cent of the Bartholomew average.

The land use in Logansport is more closely related to standard land usage than for the other five cities (Tables I and II). Unusually close comparisons occur in such land uses as residential; transportation, utilities, and communication; industrial; and community facilities which range from 90 per cent to 112 per cent of Standard Land Usage. On the other hand, 145 per cent of average standard land usage does exist in commercial land uses. Logansport has exactly the same proportion of its developed land set aside for community facilities as the Bartholomew standard, the only such instance noted in Table II.

LaPorte has about an average percentage of its developed land consumed for residential areas. It has almost twice the area in industrial space and 126 per cent of standard land usage set aside for commercial land. But, the proportion of land consumed for community facilities in LaPorte is only 60 per cent of standard usage of the comparison cities.

On a percentage basis, Bloomington falls below the average of the 28 cities in areas used for residential; commercial; transportation, utilities, and communication. In contrast to the other three land uses, Bloomington has 260 per cent of the average usage of land in industry. The extensive limestone quarries, which are scattered through several planning districts and were classified as industrial, is the primary reason for this abnormally large percentage. Since the general category of community facilities includes Indiana University, Bloomington has 163 per cent standard land usage consumed for community facilities. The streets and roads which serve the university campus were also

classified as community facilities. Therefore, only 50 per cent of standard land usage occurs in transportation, utilities, and communication.

Mishawaka has above the average land areas used for residential; commercial; industrial; and transportation, utilities, and communication uses. Mishawaka's land in community facilities is only 37 per cent of the Bartholomew standard, a fact that may influence local thinking about the availability of state and federal recreational facilities in northern Indiana.

Marion uses only 81 per cent as much land for residential purposes but uses 145 per cent as much land for commercial purposes, 125 per cent as much for transportation, utilities, and communication, and 161 per cent as much of its total developed land for industrial land uses as the Bartholomew Standard (Table II). In common with most other third class cities in Indiana, Marion also has less than average land in community facilities with only 69 per cent of standard land usage.

The 1960 employment figures for Jeffersonville indicate that 54 per cent of the labor force was employed in industries (2). This was the only employment classification that ranked considerable above the average of the Nelson standard percentage of employment. The functional classification of Jeffersonville is industrial as Nelson determined an average of 27 per cent employed by industries (2).

By using Nelson's criteria, and the 1960 employment figures, Logansport is both an industrial and transportation city. In 1960, Logansport had 60 per cent of its total labor force employed in industries. In addition, about 26 per cent of its labor forces was employed in transportation, utilities, and communication in comparison to Nelson's average of 7.1 per cent (2).

LaPorte, which has 11.2 per cent of its developed land used by industries, has 69 per cent of the total labor force employed by industries. Its functional classification is also industrial.

Bloomington is classified as a professional city. Employment figures for 1960 show that 6,184 persons are employed in educational services which even exceeds the total number of persons employed by industry. Nelson found the average is 11.1 per cent employed in professional services.

The functional classification of Mishawaka is industrial since about 75 per cent of all of Mishawaka's employment, or about three times as many as Nelson shows to be average for the United States, are employed by industries (2).

According to Nelson's criteria, Marion is classified as a diversified city since none of the classifications exceed the average by a standard deviation.

The six cities range from 65.5 per cent (in Bloomington) to 81.6 per cent (in Mishawaka) of their developed areas confined to residential areas and to transportation, utilities, and communications (Table I). The most significant differences in how cities use their land really occur in only about the one-fourth of the developed area which is used for commercial, industrial, and community facilities.

Conclusions

In an attempt to characterize the land use of six smaller cities of Indiana, the lack of data and of understanding have been apparent at many points. The resulting conclusions are of course, incomplete and tentative.

The general problem of the mapping technique and classification needs to be carried out more widely in the United States. But Bartholomew's method lends itself to a uniform and comprehensive system of collecting urban land use data. If a more generally recognized standard system of urban land use classification were more widely used, geographers no longer have to rely primarily upon employment data as a basis for the functional classification of American cities. Rather, cities could be classified on the basis of how much land is used for what purpose. No such classification system is widely used now, but such a classification scheme would be of great value to geographers and city planners.

As more attention is given to the establishment of optimum standards of urban land use, more details about the existing land uses in smaller cities could aid in finding better ways of arriving at numerical estimates of how much space a city will need in the future. Undoubtedly, geographers can do much better than they have been doing at equating myriads of urban ecological data with land use characteristics of American cities.

Literature Cited

1. BARTHOLOMEW, HARLAND. 1955. Land Uses in American Cities. Harvard University Press, pp. 147-157.
2. NELSON, HOWARD J. 1955. A Service Classification of American Cities. Economic Geography XXXI (July) : 189-210.

A Southward Decline in the Yield of Eminent Americans Illustrated and Partly Explained

Stephen S. Visher, Indiana University

The notable departure from areal uniformity in the distribution of the birthplaces of eminent Americans justifies some examples and possible explanations.

The present paper deals with the presidents of a dozen distinguished scholarly organizations plus the presidents of the United States. Its initiation was stimulated by a declaration by an exceptionally qualified native of Indiana that relatively few men of high distinction were born in Indiana. Lists were assembled of those born in each state who became eminent as indicated by their election as president.

The 12 organizations here considered, with the year of their founding, are: American Association for the Advancement of Science, 1848; National Education Association, 1857; American Chemical Society, 1876; American Bar Association, 1878; American Historical Society, 1884; Geological Society of America, 1889; American Society of Zoologists, 1890; American Psychological Association, 1892; American Botanical Society, 1894; American Physical Society, 1899; Association of American Geographers, 1904; Ecological Society of America, 1916.

The total number of presidents here considered is almost 900, of whom 75 were foreign-born (26 in Canada).

The states which yielded most of these presidents were: New York, 119; Massachusetts, 86; Ohio, 59; Illinois, 58; Pennsylvania, 56; Indiana, 36; Michigan, 29; Connecticut, 25; New Jersey and Iowa, 21 each; Wisconsin, 19; Virginia, 17; Maine and Missouri, 16; Minnesota, Nebraska and California, 12; New Hampshire, 11; Kentucky and Maryland, 10; Vermont and Kansas, 9; West Virginia, Georgia and Washington, 7; South Carolina, North Carolina and Tennessee, 6; Alabama and Utah, 5; Rhode Island and Mississippi, 4; Colorado, 3; Delaware, Louisiana, New Mexico, North Dakota and Oregon, each 2. Six states had one each. Only 5 of the 50 states yielded none (Alaska, Arizona, Nevada, Oklahoma, Florida).

Of the 34 presidents of the United States, 8 were born in Virginia; 7 in Ohio; 4 in New York; 3 in Massachusetts; 2 in Vermont and North Carolina; and 1 each in New Hampshire, New Jersey, Pennsylvania, South Carolina, Kentucky, Missouri, Iowa and Texas. Of earlier ones, 11 were born in the South but of the later ones only 2: Wilson (Virginia) and Eisenhower (Texas).

The average southward decline in the birthplaces of the presidents here considered is striking. This applies to each of the 13 groups. The states bordering Canada yielded 14 U. S. presidents and 339 others; the tier of states next south of those bordering Canada yielded 5 U. S. presidents and 233 other presidents; the Middle Atlantic states, 6 and 200; the South Atlantic states, 11 and 48; the East North Central states, 7 and 163; the South Central states (with about one-fifth of the na-

tion's population 1840-1900) yielded 2 U. S. presidents (Lincoln and Eisenhower) and 43 other presidents. The northern tier of Southern states yielded 9 U. S. presidents (8 from Virginia) and 46 others. The Deep South yielded 4 U. S. presidents and 45 others.

Statisticians declared that when several independent groups of data reveal the same trend, it is highly likely that fundamental influences are operating. The data here considered are sufficient to prove the existence of some powerful influences.

One certainly significant factor affecting the number of eminent people born in any area is the total population. Several of the states which yielded relatively many presidents were comparatively populous when the presidents were born. For example, Virginia had about twice as many people in 1790 as did any other state and was not surpassed by Pennsylvania or New York until after 1810. In 1860 (approximately the median date of the birth of the older presidents here studied) the most populous states were New York, Pennsylvania, Ohio, Illinois, Virginia, Indiana, Tennessee, Georgia, Kentucky, and Missouri. The most populous states in 1890 (approximately the date of the younger of the presidents here discussed) were New York, Pennsylvania, Illinois, Ohio, Missouri, Texas, Massachusetts, Indiana, Michigan, Virginia, Georgia, Kentucky, and Tennessee. Most of the states of small population yielded few presidents. The Rocky Mountain and Pacific states yielded only 12 and 21, but in proportion to population some states did remarkably well; for example, Massachusetts, Maine, New Hampshire, Vermont, Minnesota, and Nebraska.

Before discussing various other influences which help explain areal contrasts in yields, the 12 organizations will each be considered partly because some interesting lights are revealed.

The most distinguished of these organizations is the *American Association for the Advancement of Science*, founded in 1848. The 114 presidents were born predominantly in the North. The leading states were Massachusetts with 22; New York, 22; Ohio, 11; Pennsylvania, 8; Illinois, 6; Connecticut, 5; Michigan and Wisconsin, each 4; New Jersey, 3; 2 each from Maine, New Hampshire, Kentucky, Georgia; and 1 each from Delaware, Minnesota, Missouri, Nebraska, New Mexico, South Carolina, Washington. Of the 3 born in the Deep South, 2, the LeConte brothers, were sons of a recent immigrant from Switzerland to the University of Georgia. Canada yielded 4, Germany, 3, and one each came from China, England, Scotland, Serbia, Sweden and Switzerland. New England with 31 was by far the most productive Census Bureau Region relative to population. Of the South's 5, two served before 1900, 2 since 1942. Of the 8 born in Europe, 6 were born in the northern fringe of the continent.

A predominant share of these especially distinguished scientists had part of their training in famous northern universities and many of them held positions therein.

The second oldest organization here considered is the *National Education Association*, founded in 1857. Although most of the 102 presidents are highly distinguished, several were teachers or principals rather than prominent educators. Recently several women have been

elected. The leading states as to birthplaces are New York, 10; Massachusetts and Indiana, 8; Ohio and Illinois, 7; Pennsylvania, 6; New Hampshire, 4; Connecticut, West Virginia, Tennessee, New Jersey, Virginia, 3; 2 each from Maine, Vermont, Iowa, Missouri, Georgia, Kansas, Washington; and one each from 7 states. Only 4 were foreign-born (2 in Ireland, and 1 each in England and Germany). Twenty of these presidents were natives of New England and many of those born in New York, Ohio, Indiana, Illinois, etc., had some Yankee ancestors. Doubtless significant is the fact that New England had the first public schools, first normal schools, first colleges and universities. Only 6 presidents were born in the Upper South (Virginia to Kentucky) and only 7 in the rest of the South. Ten of these 13 Southerners were elected after 1915.

The *American Bar Association*, founded in 1878, has had among its 85 presidents numerous highly distinguished men including President W. H. Taft. The states in which most were born were New York, 16; Pennsylvania, 7; Virginia and Illinois, 5; Massachusetts, 4; Connecticut, New Jersey, Ohio, Alabama, and Mississippi, 3; 2 each were born in Maine, Georgia, Iowa, Kansas, Missouri, Texas and Wisconsin; 1 each were born in 13 other states. Only 2 were foreign-born (England and Germany). By U. S. regions, the Middle Atlantic States was the birthplace of 26; the Midwest of 18; the northern margin of the South of 10; the Deep South of 15; New England of 10, the West of 3. In proportion to population at the average date of birth of these presidents, New England and upstate New York led by a wide margin and the South rated lowest.

The *American Historical Society*, founded in 1884, had as its president Theodore Roosevelt, Woodrow Wilson, and many other highly eminent men. Eighteen of the 78 were born in Massachusetts; 8 in New York (mostly upstate); 6 in Pennsylvania; 4 each in Virginia and Illinois; 3 in Indiana; 2 each in Vermont, Connecticut, Rhode Island, Ohio, Wisconsin and Iowa; and 1 each in 5 other states. Only one was born south of Virginia, in contrast with 21 in New England and 12 in the Midwest. Four were foreign-born (Scotland, England, France and Russia).

Of the 74 presidents of the *American Chemical Society* (founded in 1876) 11 were born in Massachusetts; 10 in New York; 6 in Pennsylvania; 6 in Indiana; 5 each in Ohio, Illinois, and New Jersey; 2 in Kansas; and one each in 13 states and 10 foreign countries. The states bordering Canada yielded about ¾ of the native-born; the northern tier of the South, 4; the rest of the South, 3. The presidents elected since 1930 have come largely from the Midwest, but in proportion to population New England continued to lead. Universities especially significant in the training of chemists were Harvard, Massachusetts Institute of Technology, Michigan, Chicago, Illinois, Ohio, and California.

Of the 49 presidents of the *American Physical Society*, the leading birthstates were Ohio, 8; Massachusetts and New York, 5; Illinois, 3; Connecticut, Indiana, and Michigan, 2 each; 11 states had 1 each (only 1 in the South). Ten were foreign-born (half of the presidents elected since 1943). Universities which were prominent in the training of

physicists were Harvard, M.I.T., Yale, Princeton, Chicago and California. Several were employed by these universities or by Bell Telephone Co. or by the U. S. Bureau of Standards.

Of the 66 presidents of the *Botanical Society of America* 19 were born in New York; 9 in Michigan; 4 each in Massachusetts and Illinois; 3 each in Indiana, Wisconsin, and Iowa; 2 each in Maine, Nebraska and Missouri; and 1 each in 4 states. The South yielded 2; Canada, 2; other foreign lands, 5. The high ranks of New York and Michigan are related to stimulating teaching of botany for decades at Cornell and Columbia and at Michigan and its agricultural college. As to those from Illinois, Indiana, Iowa, and Wisconsin, J. M. Coulter (Chicago) helped train several future presidents.

Of the 47 presidents of the *Ecological Society of America*, Illinois yielded 6; New York, 5; Ohio and Michigan, 4; Connecticut, Pennsylvania, Indiana, Iowa and Nebraska, 3 each; Minnesota and Texas, 2 each; and 5 states had 1 each. Curious is the fact that only 2 of the 47 ecologists were born in sizable cities, none in Boston, New York, Philadelphia or Chicago, which cities yielded relatively many distinguished men. Only 1 of the ecologists was foreign-born. Ten of the 47 were students of H. C. Cowles at Chicago, who was successively president of the organizations of geographers, ecologists, and botanists here studied.

Of the 78 presidents of the *American Society of Zoologists*, 14 were natives of New York; 8 of Illinois; 5 of Indiana; 4 each of Maryland, Pennsylvania, Michigan and Ohio; 3 each of Connecticut and Iowa; 2 each of Massachusetts and Wisconsin. Three came from the Deep South; 7 were foreign-born (6 of them president since 1946). (Three of Indiana's 5 reflect the influence of David Starr Jordan during his fertile years in Indiana, as do 6 other presidents in education, geology, botany, psychology.)

The *American Psychological Association* has had among its 67 presidents several highly eminent men including William James, John Dewey, Lewis Terman, and 2 presidents of the American Association for the Advancement of Science (Cattell and Thorndike). The leading states are: Pennsylvania, Indiana and Illinois with 6 each; Massachusetts, New York and California, each 5; Ohio and Nebraska, 4; Iowa, 3; Vermont, New Jersey, South Carolina and Minnesota, 2 each; and 1 each from Connecticut, Virginia, West Virginia, Missouri, Wisconsin, Utah, Wyoming, North Dakota; 2 each from Canada and India; and 4 other foreign-born. The relatively high yield from the northeastern states is related to the influence of professors at Columbia, Harvard and Clark. The South yielded 4, 2 from South Carolina. The yield from the West, especially California, is notable (12). Indiana's high rank reflects the influence of W. L. Bryan, president of Indiana University and an early president of this association.

The *Geological Society of America* had of its 73 presidents 14 born in New York (mostly upstate); Massachusetts, 8; Ohio, 5; Pennsylvania and California, 4 each; 3 each from Minnesota and Missouri; and 2 each from West Virginia, Illinois, Wisconsin, Texas and Washington. Nine states each yielded 1. Nine were born in Canada (5 in Ontario).

The states bordering Canada yielded 38; the Midwest 18; the Pacific states 6. Of the 8 born in the South, 2 came from West Virginia, 2 from Texas, and 1 from Kentucky. The eminence of this group of presidents is revealed partly by the fact that 8 of them became president of the American Association for the Advancement of Science. Many of the geologists were partly trained at Harvard, Massachusetts Institute of Technology, Yale, Columbia, Chicago, Wisconsin and California. Many of them were partly employed by these universities and by the U. S. or Canadian Geological Survey. Of the 4 born in Europe, Scotland yielded 2, Sweden 1 and northern Germany 1.

Of the 64 presidents of the *Association of American Geographers*, 7 each were born in Massachusetts, New York and Michigan; 6 in Ohio; 5 in Illinois; 3 in Pennsylvania; and 2 each in Virginia, Kentucky, Missouri, Wisconsin, Minnesota and Washington; and 1 in each of 6 western states and 3 others. By latitudinal zones, 3 were born in Canada; the states bordering or near Canada yielded 34 of the 56 native Americans. The most northern tier of Southern states yielded 5; the Deep South 1. The relatively large number from Massachusetts and New York reflects the influence of W. M. Davis at Harvard (the founder of the Association). The Michigan total reflects the influence of a remarkably stimulating teacher at the state normal school at Ypsilanti, Mark Jefferson, 4 of whose students became president. R. D. Salisbury at Chicago contributed to the advanced training of 12.

Further Probable Explanations

For each of the groups studied there is an average southward decline in yield which is so significant that possible explanations are well worth consideration.

Southward changes in climate are considerable and have had varied consequences. The climate of the South is more often "enervating" than is that of the North, which is more "stimulating," putting a premium upon human vigor, persistence and planning.

The indirect influences of the climate are vastly more significant than are the direct ones. They have led to differences in the types of agriculture and other methods of winning a livelihood, also in the development of transportation and communication facilities, and in the type of urbanization.

In the U. S. east of the Rocky Mountains there is an appreciable latitudinal difference in social ideals. Many more of the Southerners are "easy-going," sociable rather than aggressive, and far less ambitious to "get ahead" than is true of many of the Northerners. Also certain types of people are relatively more numerous in the North than in the South, including those with some Yankee, Scotch, early German, or Scandinavian ancestry. Conversely, Negroes and "poor whites" are far more numerous in the South than in the North. None of these presidents was a Negro, and almost none were from families which were economically notably below the local average.

Differences in education certainly are a partial explanation of the regional contrasts in the yield. The North has had various colleges and universities which helped train and employ many of these presidents,

while the South had very few such institutions. Exceptionally stimulating university professors have also played an important role.

Areal differences in the people clearly are important. Needed are considerable numbers of ambitious, self-confident, optimistic, able, energetic people who persistently endeavor to progress and assist others to do so. People with these qualities, rare everywhere, are less rare in the North than in the South.

Indiana has ranked lower in the yield of eminent persons in proportion to population than nearby states except Kentucky partly because it has done distinctly less well than these other states in affording advanced education and generous opportunities for its talented young men. The poorer facilities and the loss to other states of most of the eminent people born in Indiana has been costly in various ways including less effective encouragement of talented young Hoosiers.

HISTORY OF SCIENCE

No meeting in 1963

MATHEMATICS

No meeting in 1963

PSYCHOLOGY

No meeting in 1963

PHYSICS

Chairman: PAUL BENDER, Goshen College

CONSTANTINE KOLITSHOW, Indianapolis, was elected chairman for 1964

ABSTRACTS

The Ballistic Paths of Tektites. D. L. SHIRER and J. H. LIESKE, Valparaiso University.—It has been suggested that the peculiar nature of the Australian tektite strewn field resulted from a large meteoritic or cometary impact upon the Antarctic continent. Computation of the ballistic orbits of the tektite-like particles seems to rule out this theory if the tektites originated in their final form, as some other authors suggest, instead of being ablated from larger impactites.

A Simple Method of Testing Quarter-wave Plates. ROBERT L. HENRY, Wabash College.—The extent to which a quarter-wave plate departs from its specifications can be determined by a simple test procedure which has also been found to be an instructive student laboratory exercise in the properties of polarized light. The method involves a minimum of equipment and gives quantitative results for the phase difference introduced by the quarter-wave plate as a function of wavelength. The plate to be tested is placed between crossed Polaroids (or Nicol prisms), illuminated with monochromatic light of the desired wavelength, and rotated in its own plane until the transmission of the system is a maximum. A simple expression is derived which gives the desired phase difference in terms of the ratio of the maximum intensity to the minimum intensity transmitted by the system when the second Polaroid (the "analyzer") is rotated in its own plane.

Diffusion Heating and Cooling of Thermal Neutrons in Water[1]

M. M. Bretscher and J. F. Meyer, Valparaiso University

The diffusion heating effect of thermal neutrons in light water has been investigated by measuring the diffusion length as a function of boric acid concentration. Diffusion lengths were obtained by a negative source technique while the boric acid concentrations were determined by both pulsed neutron methods and by direct chemical analysis. From these measurements the diffusion parameters of thermal neutrons in water have been obtained. Preliminary results for the microscopic absorption cross section of hydrogen σ_a, the diffusion coefficient $\overline{D}_o$, and the diffusion heating coefficient C of light water are 0.323 $\pm$ 0.032 barn, 37,135 $\pm$ 1,196 cm^2 sec^{-1}, and 2,836 $\pm$ 598 cm^4 sec^{-1} respectively. Pulsed neutron techniques have also been used to obtain independent data for these same diffusion parameters with the results $\sigma_a = 0.321 \pm 0.005$ barn, $\overline{D}_o = 37{,}651 \pm 545$ cm^2 sec^{-1}, and $C = 5{,}843 \pm 887$ cm^4 sec^{-1}. Both sets of data are in favorable agreement with recently published results.

Introduction

For a large weakly absorbing system the energy distribution of neutrons in thermal equilibrium with the atoms (or molecules) of the medium is given by the Maxwell-Boltzmann distribution law,

$$N(E)\,dE = 2\pi\,(\pi kT)^{-3/2}\,E^{1/2}\,e^{-E/kT}\,dE \qquad (1)$$

where $N(E)\,dE$ is the fraction of thermal neutrons with energies between E and $E+dE$, k is the Boltzmann constant, and T is the absolute temperature of the medium. In many practical situations $N(E)$ deviates significantly from the ideal Maxwellian spectrum because of the combined effects of neutron absorption and neutron leakage from the system.

In steady state situations, where the number of thermal neutrons per unit volume is not a function of time, $N(E)$ progressively deviates from the Maxwell-Boltzmann distribution as the absorption within the medium increases. To maintain steady state conditions in a large medium with negligible leakage, neutrons must diffuse into a given volume element at the same rate as they are lost by absorption. Since most thermal neutron absorption cross sections vary as 1/v, where v is the speed of the neutron, the average energy at which neutrons are absorbed is less than the average energy of those compensating neutrons diffusing into the volume element. As a result, the neutron distribution function $N(E)$ has a deficiency of low energy neutrons so that the average neutron energy is greater than that given by the Maxwell-Boltzmann distribution. According to kinetic theory the average energy is directly proportional to the absolute temperature. Therefore, the temperature characterizing the thermal neutron energy distribution for the case of

1. Much of the instrumentation used in these measurements was purchased out of grants from the Division of Reactor Development of the U. S. Atomic Energy Commission. This assistance is gratefully acknowledged.

1/v absorption is above that of the medium. For this reason the effect of neutron absorption on N(E) is called diffusion heating.

In a small weakly absorbing medium the main effect which removes neutrons is leakage. Since a fast neutron has a greater probability of escaping from the system than a slow one, the medium continuously loses neutrons whose average energy is greater than that of the neutrons remaining in the system. This effect, which becomes more pronounced as the leakage rate increases, shifts the peak of the neutron energy spectrum into the direction of smaller energies thereby characterizing N(E) with a temperature lower than that of the medium. Thus, the effect of leakage on the neutron energy spectrum is just the opposite of diffusion heating and is called diffusion cooling.

The distortion of the neutron energy spectrum from the ideal Maxwell-Boltzmann distribution due to absorption (diffusion heating) and leakage (diffusion cooling) effects is summarized in Fig. 1. One

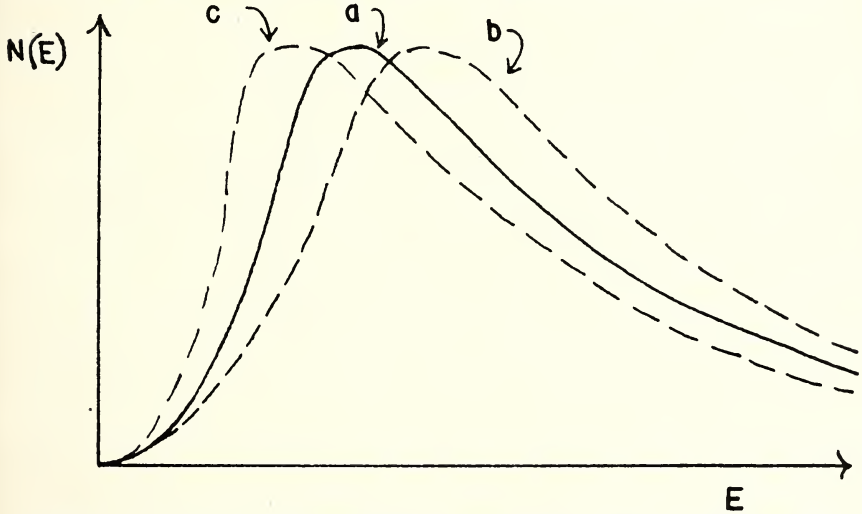

Figure 1. Distortion of thermal neutron energy spectrum due to absorption and leakage effects. a) Maxwell-Boltzmann distribution, b) distribution with 1/v absorption, no leakage, c) distribution with leakage, no absorption.

may investigate the diffusion heating effect quantitatively by measuring the thermal neutron diffusion length as a function of the concentration of a strong 1/v neutron absorber added to the system. By measuring the time rate of decay of thermal neutrons in a weakly absorbing medium as a function of the size (which determines the leakage rate) of the system one may determine the quantitative effects of diffusion cooling.

Theory of Measurement—Diffusion Heating

The steady state, source-free thermal neutron diffusion equation (3) is

$$D_o(E)\ \nabla^2 n(\vec{r},E) - v\ \Sigma_a(E)\ n(\vec{r},E) = 0 \qquad (2)$$

where $n(\vec{r},E)$ is the number of thermal neutrons per unit volume per unit energy at position $\vec{r}$ and having energy E. $D_o(E)$ is the energy-

dependent diffusion coefficient and $\Sigma_a(E)$ is the macroscopic absorption cross section. For a medium whose thermal neutron absorption cross section varies as 1/v this equation may be written as

$$\nabla^2 n(\vec{r}) - \kappa^2 n(\vec{r}) = 0 \tag{3}$$

where $\Sigma_a = \lambda/v$, $\kappa^2 = \lambda/\overline{D}_o$, and where

$$\overline{D}_o = \frac{\int_o^\infty D_o(E)\, N(E)\, dE}{\int_o^\infty N(E)\, dE}$$

For $\kappa^2 = 0$, N(E) is given by the Maxwell-Boltzman distribution (Eq. 1). Now $\overline{D}_o$ may be thought of as a function of κ^2 and so can be expanded in a Taylor series about the point $\kappa^2 = 0$, corresponding to an absorption-less medium. Then,

$$\overline{D}_o(\kappa^2) = \overline{D}_o(0) + \kappa^2 d\overline{D}_o/d\kappa^2 + \cdots .$$

Hence,

$$\lambda = v\,\Sigma_a = \overline{D}_o(\kappa^2)\,\kappa^2 = \overline{D}_o(0)\,\kappa^2 + C_h\,\kappa^4 + \cdots \tag{4}$$

where the diffusion heating coefficient C_h is defined as

$$C_h = d\overline{D}_o/d\kappa^2\Big|_{\kappa^2 = 0}. \tag{5}$$

In order to simplify the notation $\overline{D}_o(0)$ shall hereafter be written as $\overline{D}_o$.

Now suppose boric acid, which is a 1/v absorber, is dissolved in a large volume of water. Eq. (4) then becomes

$$-v\,\Sigma_a(H_3BO_3) = v\,\Sigma_a(H_2O) - \overline{D}_o\,\kappa^2 - C_h\,\kappa^4 \tag{6}$$

where higher order terms in κ^2 have been neglected. One may measure κ^2, which is just the square of the reciprocal of the thermal neutron diffusion length, as a function of boric acid concentration by a negative source technique (1). Briefly, this method consists of measuring the neutron density function $n(\vec{r})$ along the axis of a large cylindrical moderator with a Pu-Be neutron source located on the base of the cylinder. Two axial distributions are needed. One is taken with a cadmium plate, having the same dimensions as the base of the cylinder, covering the neutron source while the second distribution is measured with the cadmium plate removed. For regions away from the top of the cylinder the point by point difference of the two axial distributions can be fitted to the equation

$$n(z) = A\, e^{-\gamma z} \tag{7}$$

where A is a constant and where

$$\kappa^2 = \gamma^2 - (2.405/R)^2. \tag{8}$$

R is the effective radius of the cylinder. Thus, the measured distributions determine γ from which κ^2 is calculated. Now $v\,\Sigma_a$ (H_3BO_3) may be measured directly by pulsed neutron techniques (5) or calculated from the known 1/v absorption cross section of boron (5) and the measured concentration of H_3BO_3. This concentration may be determined by a standard chemical analysis involving boric acid titration with mannitol.

As seen from Eq. (6), a least squares fit of the data to a parabola in κ^2 determines the diffusion parameters $v\,\Sigma_a\,(H_2O)$, $\overline{D}_o$ and C_h.

Theory of Measurement—Diffusion Cooling

Following a neutron burst, which may result from a pulse of deuterons striking a tritium target, the thermal neutron distribution in a source-free homogeneous medium is governed by the time-dependent diffusion equation

$$\overline{D}_o\ \nabla^2 n(\vec{r},t) - v\,\Sigma_a n(\vec{r},t) = \frac{\partial}{\partial t} n(\vec{r},t). \tag{9}$$

Eq. (9) may be solved by the method of separation of variables. After long times following each neutron burst the neutron distribution is well represented by the fundamental mode. For a pulsed neutron source located on the axis but beneath a cylindrical water moderator, the thermal neutron distribution corresponding to this fundamental mode is

$$n(r,z,t) = A\,J_o(2.405\,r/R)\,\sin(\pi z/H)\,e^{-\alpha t} \tag{10}$$

with $$\alpha = v\,\Sigma_a(H_2O) + \overline{D}_o\,B^2 \tag{11}$$

and $$B^2 = (2.405/R)^2 + (\pi/H)^2. \tag{12}$$

R and H are the extrapolated radius and height of the cylinder while B^2 is called the geometric buckling of the system. Now $\overline{D}_o$ is averaged over N(E) which depends on the neutron leakage rate and so on the size and shape of the system. Therefore, $\overline{D}_o$ may be expanded in a Taylor series about $B^2 = 0$, which corresponds to an infinitely large system for which there is no leakage.

$$\overline{D}_o(B^2) = \overline{D}_o(0) + B^2\,d\overline{D}_o/dB^2 + \cdots \tag{13}$$

Eq. (11) now becomes

$$\alpha = v\,\Sigma_a(H_2O) + \overline{D}_o\,B^2 - C_c\,B^4 \tag{14}$$

where higher order terms in B^2 have been neglected and where now $\overline{D}_o$ has the meaning $\overline{D}_o(0)$. The diffusion cooling coefficient C_c is defined by the equation

$$C_c = -\,d\overline{D}_o/dB^2\Big|_{B^2=0}. \tag{15}$$

Measurement of the decay constant α by pulsed neutron techniques (2) for a variety of cylinder sizes yields data which may be fitted by the least squares process to a parabola in B^2 thereby determining the constants $v\,\Sigma_a(H_2O)$, $\overline{D}_o$ and C_c.

The similarity between Eqs. (6) and (14) and between Eqs. (5) and (15) should be noted. κ^2 is equivalent to a negative geometric buckling B^2 while the decay constant α may be correlated with the negative poison $-v\,\Sigma_a(H_3BO_3)$. Thus, the diffusion heating and cooling coefficients are identical.

$$C_h = C_v = C \tag{16}$$

Experimental Arrangement

The experimental arrangement for the determination of α by pulsed neutron methods has been discussed previously (2) and will not be repeated here. A 15 gallon drum 38 cm in diameter, 55 cm deep, and lined with a cadmium sheet 0.020 inch thick was used for the diffusion heating measurements. Five Pu-Be neutron sources having a combined source strength of 8.0×10^6 neutrons per second were symmetrically

arranged around the axis of the tank on its base. Neutrons were detected by means on a neutron-sensitive scintillation probe manufactured by the Nuclear Chicago Corporation (Model DS8-10). The 96 percent enriched B^{10}, Zn(Ag) activated crystal had a diameter of ¾ inch, a thickness of $\frac{3}{16}$ inch, and was mounted at the end of a lucite light pipe 42 inches long. Both chemical and pulsed neutron techniques were used to determine $v\,\Sigma_a(H_3BO_3)$. Deionized water having a resistivity of about 1×10^7 ohm - cm and a temperature of 24 ± 1° C was used for all the measurements.

Experimental Results

A summary of the experimental data for both the diffusion heating and diffusion cooling measurements is shown in Table I. The data was

TABLE I. Experimental Data

Diffusion Heating		Diffusion Cooling	
κ^2 (cm^{-2})	$v\,\Sigma_a$ (H_3BO_3) - sec^{-1}	B^2 (cm^{-2})	α (sec^{-1})
0.1316 ± 0.0018	0.000	0.000	(4.68 ± 0.04)10^3
0.3303 ± 0.0075	(7.65 ± 0.12)10^3	0.050	(6.58 ± 0.06)10^3
0.4146 ± 0.0052	(11.65 ± 0.06)10^3	0.075	(7.54 ± 0.01)10^3
0.6350 ± 0.0089	(19.60 ± 0.11)10^3	0.100	(8.41 ± 0.02)10^3
0.7471 ± 0.0090	(25.06 ± 0.14)10^3	0.150	(10.25 ± 0.03)10^3
0.9305 ± 0.0180	(32.12 ± 0.14)10^3	0.200	(11.98 ± 0.02)10^3
1.1211 ± 0.0505	(41.91 ± 0.17)10^3	0.250	(13.82 ± 0.10)10^3
1.4218 ± 0.0757	(54.01 ± 0.18)10^3	0.300	(15.46 ± 0.13)10^3
1.4900 ± 0.0134	(56.29 ± 0.60)10^3	0.350	(17.34 ± 0.10)10^3
1.8166 ± 0.0295	(72.31 ± 0.35)10^3	0.400	(18.57 ± 0.21)10^3
		0.450	(20.49 ± 0.23)10^3
		0.500	(22.13 ± 0.17)10^3
		0.550	(23.66 ± 0.27)10^3
		0.600	(25.21 ± 0.20)10^3

analyzed using an extrapolation distance of 0.32 cm. A plot of the decay constant versus the geometric buckling is shown in Fig. 2. Data for the diffusion cooling experiment is plotted in the first quadrant while the diffusion heating results are shown in the third quadrant. The departure of the data from a straight line is a clear indication of the diffusion cooling and diffusion heating effects.

The diffusion parameters $v\,\Sigma_a(H_2O)$, $\overline{D}_o$, and C are determined by using a least squares process to fit the data in Table I to Eqs. (6) and (14). The results are shown in Table II along with some recently published data. Since the absorption cross section of oxygen for thermal neutrons is completely negligible, the 1/v microscopic absorption cross section of hydrogen σ_a^H may be calculated from $v\,\Sigma_a(H_2O)$.

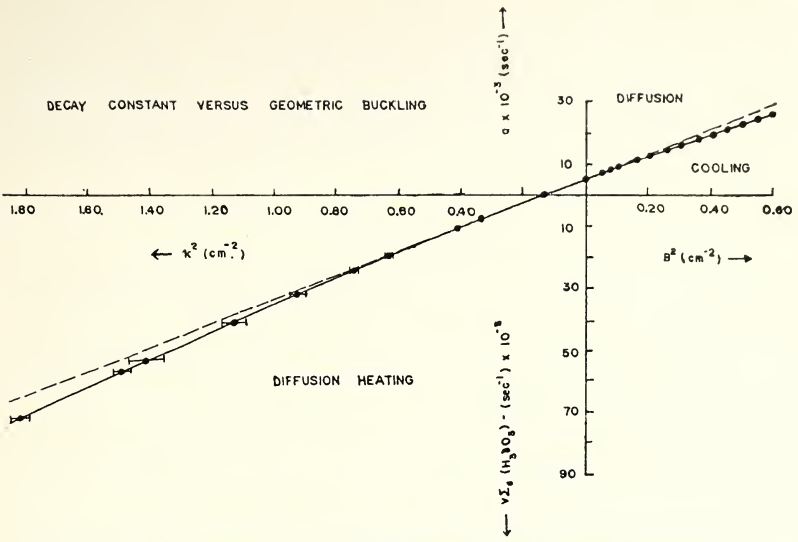

Figure 2. Least squares fit of decay constant versus geometric buckling.

TABLE II. Experimental Results
Thermal Neutron Diffusion Parameters For Water

Reference	$v\Sigma_a$ (sec^{-1})	σ_aH (mb)	$\overline{D}_o$ (cm^2 — sec^{-1})	C (cm^4 — sec^{-1})	Method
This work	4,748 ± 473	323 ± 32	37,135 ± 1,196	2,836 ± 598	H_3BO_3
This work	4,713 ± 67	321 ± 5	37,651 ± 545	5,843 ± 887	Pulsed
(4)	4,780 ± 27	325 ± 2	37,503 ± 366	5,116 ± 776	Pulsed
(6)	4,810 ± 24	327 ± 2	35,850 ± 100	2,900 ± 350	H_3BO_3
(6)			37,590	3,116	Theory

Summary

The diffusion parameters of thermal neutrons in water have been determined by two independent methods. Except for the diffusion cooling-heating coefficient, the results of the pulsed neutron measurement are in very favorable agreement with those obtained by the boron poisoning technique and likewise agree with recently published data. The two independently measured results for the diffusion heating coefficient are self-consistent and agree with the theoretical value. Although the measured values for the diffusion cooling coefficient are equal within experimental errors, they do not agree with the values obtained for the diffusion heating coefficient. Theoretically C_v and C_h are identical. One is inclined to place more confidence in the results from the boron poisoning measurements because the data covers a greater range of buckling values ($-\kappa^2$) than can be obtained in the pulsed neutron experiments. For small systems (large B^2) errors in the extrapolated dimensions in-

troduce relatively large errors in B^2. Because of the rapid rate at which neutrons leak out of a small system data may be taken before the fundamental mode has been achieved. For these reasons the diffusion heating experiment should yield a more reliable result for C than that obtained by pulsed neutron techniques. However, errors introduced by the neglect of the κ^6 and B^6 terms in Eqs. (6) and (14) may be significant and this matter needs more careful study .

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PLANT TAXONOMY

Chairman: Joseph Hennen, Indiana State College
Robert Petty, Wabash College, was elected chairman for 1964

ABSTRACTS

Asiatic Species of Pileolaria (Basidiomycetes, Uredinales). Joe F. Hennen, Indiana State College and Purdue University.—This is a second report on work done toward a proposed taxonomic monograph of the rust genus *Pileolaria* for the world. North American species were summarized at the 1962 Indiana Academy of Science meetings. This work is based primarily on literature survey and microscopic study of herbarium specimens from all available pertinent sources.

According to the authors interpretation, there are seven known species of *Pileolaria* in Asia. One of these is apparently a previously undescribed species. They are all parasites on members of the *Anacardiaceae*. They are: 1. *Pileolaria klugkistiana* (Dietel) Dietel on *Rhus javanica* L. (includes *R. chinensis* Miller and *R. semialata* Murry) from mainland China, Formosa, Japan and Korea, *R. potaninii* Maxim. from China, *R. punjabensis var. nucipersica* (L.) Schneid. from China, *R. hypoleuca* from China and *Rhus sp.* from India (Himalayan Mts.); 2. *P. shiraiana* Ito on *Rhus delvayi* from China and Japan, *R. sylvestris* Sieb. and Zucc. from China and Japan, *R. verniciflua* Stokes from China, *R. succedanea* L. from China and Ryukus Is., *R. trichocarpa* Miq. from Japan and N. Korea and *R.* (*Toxicodendron*) *radicans* L. from Japan; 3. *P. brevipes* Berk. and Rav. on *Rhus ambigua* Lavallee (*R.* (*Toxicodendron*) *radicans* L.?) from Japan and Formosa; 4. an apparently undescribed short-cycled form of *Pileolaria brevipes* on *Rhus radicans* from Japan; 5. *P. terebinthi* (D.C.) Cast. on *Pistacia chinensis* Bge. and *Pistacia weinmanifolia* from China; 6. *P. Pistacia* Tai and Wei on *Pistacia chinensis* Bge. from China, Formosa, and the Philippine I.; 7. *P. Cotini-coggygriae* Tai and Cheo on *Cotinus coggygria Scop.* from China.

Miocene Charophytes from Ixtapa, Chiapas, Mexico. Fay Kenoyer Daily, Jean H. Langenheim and J. Wyatt Durham, Butler University, Harvard University and University of California.—Some washed oogonia of fossil charophytes were received for study by the senior author in the fall of 1961. These specimens are part of the plant and animal fossils from Chiapas, Mexico, undergoing an intensive study coordinated by Durham. He has supplied the geological data and Jean H. Langenheim isolated the fossil charophytes and added paleobotanical information.

The charophytes were collected from detrital amber-bearing beds in a tuffaceous sequence exposed along the Rio de Salina. Much of the bedding suggests lacustrine deposition which is locally substantiated by

the occurrence of fresh-water gastropods. This sequence appears to mark the inception of extensive vulcanism in this area and to be late Miocene in age.

Four slides showing representative charophytes isolated from the formation were shown. They are photographs of the lime-shells, whole and in thin section, as well as isolated structures. Three genera are represented with one new species and a new subspecies. Several specimens considered to be abnormal were included. Descriptions and illustrations will be published.

Algae Found Growing in Plastic Enclosures Covering Ears of Popcorn Plants

William A. Daily and Ray T. Everly, Lilly Research Laboratories and Purdue University

In a field experiment on the State Hospital farm at Evansville, Indiana, during the period from August 1 to October 10, 1962, new, previously unopened, plastic bags were placed over ears of popcorn and securely tied in place. The purpose was to prevent infestation of the ears by the *Angoumois* grain moth. The earliest time of covering an ear was when the tassel appears in the whorl but prior to pollen shedding by a week or ten days. Others were put on at about pollen-shedding time, and the remaining bags were put on when the ears were in full silk.

Early in October some of the bags contained very wet green growths of algae. The contents of four of these bags were examined microscopically and the algae noted were: Chlorophyceae-*Chlorella sp.*, *Chlorococcum sp.*, *Scenedesmus sp.* and *Chlamydomonas sp.* (Dr. Harold Bold, University of Texas, suggested not assigning specific names to any of the four genera), Myxophyceae-*Plectonema nostocorum* Born. (Identified by Dr. Francis Drouet, Philadelphia Academy of Natural Sciences.) A very few protozoan cysts were also observed but not identified.

Samples of the contents of the four bags were cultured in Bristol's algal medium, but this procedure did not add any new names to the list.

In this short study of the unusual algal aspect of the field experiment, the most plausible explanation for the presence of the algae in the bags is that vegetative cells and/or spores and cysts settled out from the air onto the popcorn plants. Insects and higher animals acting as vectors of dissemination cannot be ruled out, but research done in the past few years weighs heavily in favor of air distribution.

Schlichting (1) published a review of work in this general field of air dispersal of organisms as well as his researches and noted many kinds of algae and some protozoa in the air, but did not cite filamentous myxophyceae or the genera *Scenedesmus* and *Chlamydomonas*. Very lately, Maguire (2) published a thorough study concerning the passive dispersal of small aquatic organisms in which these two genera and *Plectonema* are cited.

The algal collections were preserved in liquid as well as by dried herbarium specimens and are on file in the Ray C. Friesner Memorial Herbarium of Butler University.

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Rush Woods, A Lowland Extension of the Beech-Maple Climax, Montgomery County, Indiana

Robert Petty and Daniel Harwood
Wabash College and East Union School

INTRODUCTION

Southwestern Montgomery County is characterized by a mildly rolling landscape derived from a complex of Wisconsin morainal deposits. Abberant drainage, typical of this portion of the Tipton Till Plain, produced a presettlement landscape dotted with wide depressional troughs, shallow swamps and wet prairie. Descriptions by the first white settlers (circa 1820) record "a land of the shakes and fever" where malaria came routinely with the rigors of frontier life. Farm land had to be "made" either by clearing the timbered high ground or draining the low land. In the last 50 years extensive drainage ditches and tiled fields have eliminated most of the natural swamps, however, numerous depressional areas still exist, where the surface soil is at or near field capacity much of the year. Rush Woods is a remnant of virgin timber occupying a depressional phase of Brookston silt loam. The stand has been preserved by the owners, Helen and Doyne Rush of Alamo, Indiana, out of a genuine interest in its natural history. The authors are grateful to them for permission to conduct the study.

Location and History of the Stand

Rush Woods is located in the southeast quarter of Section 27, T18N, R6W, Montgomery County, Indiana. The woods is bisected by a narrow abandoned road which was last used in 1907. Since that time the roadbed has passed through an extended early succession and only recently have maple (*Acer saccharum*), tulip poplar (*Liriodendron tulipifera*), and oak (*Quercus macrocarpa*) begun to invade this strip. In the low area at either side of the road, a large stand of elm (*Ulmus rubra* and *U. americana*) was dominant until 1952. At that time *Ceratocystis ulmi* became prevalent in the stand. Subsequent death of the large elm has opened the crown in the stand's interior (Plate I-2). A small section at the southern edge of the woods was selectively cut in 1902. This section is currently dominated by sugar maple and basswood, (*Tilia americana*). The remaining area has been relatively undisturbed except for the natural processes of death and windthrow.

Procedure

During the late summer and fall of 1961 four areas were delimited within the woods, their total area comprising 12 acres. The corners of each area were marked with steel fence posts to allow subsequent analysis. The total tally area involved all of the stand except a strip 20 yards in width at each edge of the woods and did not include the abandoned road. All stems 4 inches *dbh* and above were measured to the nearest 0.1 inch and recorded (Table 1). From these data, relative basal

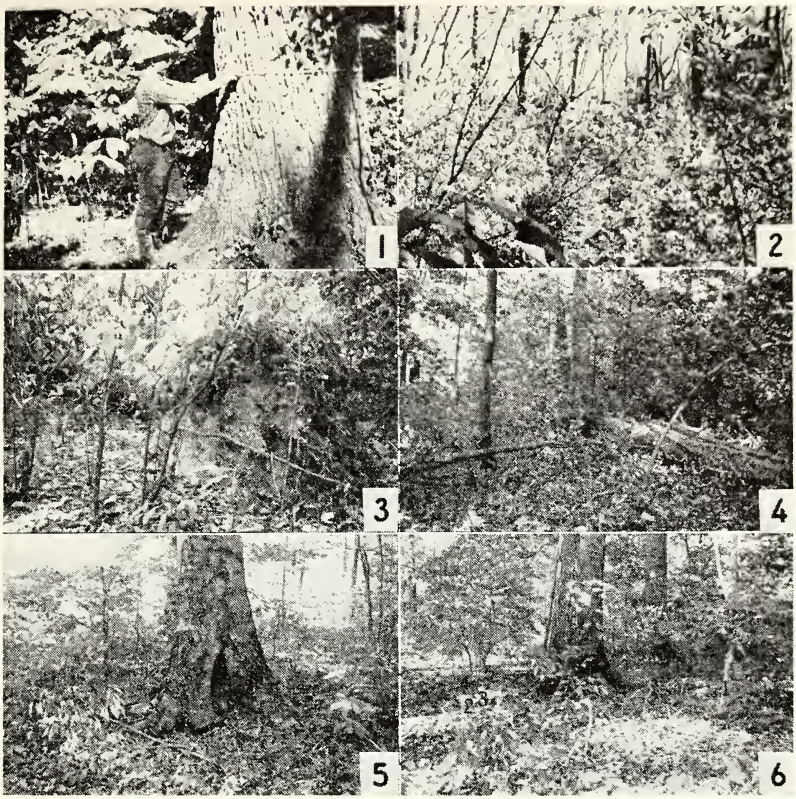

PLATE I (1) *Quercus macrocarpa* 47.2 inches *dbh*, located near the center of the woods.

(2) Extensive blight death of mature *Ulmus americana* and *Ulmus rubra* in the low interior of the stand, with vigorous regrowth of elm saplings and spicebush (*Lindera benzoin*). Man gives scale.

(3), (4) Two of the many windthrown stems which characterize aspect in the stand's interior.

(5) *Fagus grandifolia* at the limits of moisture tolerance, showing "alligator fissuring," butt-swell and basal decay typical of beech on poorly drained soils.

(6) *Fagus grandifolia* showing excessive root sprouting in poorly drained soil; these near the west edge of the woods.

area and relative density per acre were determined for each species (Table 2). Species nomenclature follows Gleason and Cronquist (1). Available moisture at the 6-inch soil level was measured with Bouyoucos plaster blocks and potentiometer on a weekly basis from August 2 to October 20. Soil texture analysis was made using the Bouyoucos hydrometer method.

TABLE 1. Size Class Midpoints (12-acre tally)
Rush Woods, Montgomery County, Indiana

Species	Diameter in Inches 6	10	14	18	22	26	30	34	above 36	total stems
Fagus grandifolia	47	2	10	27	32	45	14	2		179
Acer saccharum	367	64	17	2	1					451
Liriodendron tulipifera	5	13	17	21	3	3				62
Tilia americana	2	11	10	5	1					29
Ulmus rubra	7	11	9	4	1					32
Quercus rubra	2	4	8	5	1		1			21
Quercus macrocarpa		1	1						2	4
Prunus serotina	2	8	4	2						16
Fraxinus americana	5	4	2	1						12
Carpinus caroliniana	16									16
Ulmus americana	7		4							11
Fraxinus pennsylvanica	2	3	3							8
Juglans nigra	1	5		2						8
Gymnocladus dioica	2	2			1					5
Carya cordiformis		4	1							5
Carya ovata	2	1				1				4
Celtis occidentalis	3	2								5
Sassafras albidum	1	2								3
Quercus prinoides	3									3
Juglans cinerea				1						1
Carya glabra			1							1
Acer Negundo	1	1								2
Aesculus glabra	1									1
									total	879

TABLE 2. Stand Attributes

Species	B_2	B_3	D_2	D_3	V_3
Fagus grandifolia	33.47	50.41	19.47	20.39	35.40
Acer saccharum	10.98	16.55	49.02	51.38	33.97
Liriodendron tulipifera	7.49	11.28	6.74	7.06	9.17
Tilia americana	2.59	3.89	3.15	3.30	3.60
Ulmus rubra	2.32	3.49	3.48	3.64	3.57
Quercus rubra	2.19	3.20	2.28	2.39	2.80
Q. macrocarpa	2.02	3.03	.43	.45	1.74
Prunus serotina	.95	1.42	1.74	1.82	1.62
Fraxinus americana	.93	1.39	1.30	1.36	1.36
Carpinus caroliniana	.2	.30	1.74	1.82	1.06
Ulmus americana	.48	.73	1.19	1.25	.99
Fraxinus pennsylvanica	.93	.97	.87	.91	.94
Juglans nigra	.52	.77	.87	.91	.84
Gymnocladus dioica	.38	.57	.54	.56	.56
Carya cordiformis	.29	.43	.54	.56	.50
C. ovata	.36	.53	.43	.45	.49
Celtis occidentalis	.19	.28	.54	.56	.42
Sassafras albidum	.14	.20	.32	.33	.27
Quercus prinoides	.04	.05	.32	.33	.19
Juglans cinerea	.12	.17	.11	.11	.14
Carya glabra	.08	.11	.11	.11	.11
Acer Negundo	.07	.10	.08	.08	.09
Aesculus glabra	.01	.01	.11	.11	.06

Results

Twenty-three tree species were recorded in the 12-acre tract with 879 individuals above 4 inches *dbh* (Table 1). *Fagus grandifolia* contributed 33.47 sq. ft. per acre basal area; *Acer saccharum* and *Liriodendron tulipifera* were co-dominants with 10.9 and 7.4 respectively. Numerical expression of density and basal area for all species is presented in Table 2. Attribute symbols are those of Lindsey (3): D_2, density per acre; D_3, relative density; B_2, basal area per acre; B_3 relative basal area; Y_3, importance value, here the average of the D_3 and B_3 figures. While beech contributed the majority of larger stems, the largest diameter recorded was of bur oak (*Quercus macrocarpa*), 47.2 inches *dbh*. Another individual of the same species measured 46.7 (Plate I-1).

Characterization of the soil moisture pattern in late summer may be served by comparing data from Rush Woods with concurrent readings taken in a mesic forest in Parke County (8). Both areas received the same total precipitation.

	Percent Available Moisture (Weekly Interval)								
	Aug. 2							Oct. 20	
Mesic Upland (Allee Woods)	70	73	40	50	32	21	24	57	60
Mesic Lowland (Rush Woods)	90	92	85	89	78	38	37	78	80

Texture analysis of soil samples taken throughout the tract averaged 45% clay, 13% silt and 42% sand. The pH at the 6-inch level ranged from 4.6 to 5.6.

Discussion

In an extensive study of floodplain phytosociology, Lindsey, et al (5). list 15 tree species of major importance in mature bottomland forests. Their list includes 13 of the 23 species tallied in the Rush Woods given here in order of increasing flood-susceptibility: *Fraxinus pennsylvanica, Ulmus rubra, U. americana, Juglans* sp., *Acer Negundo, Quercus macrocarpa, Gymnocladus dioica, Celtis occidentalis, Tilia americana, Aesculus glabra, Carya cordiformis* and *Quercus rubra.* In his analysis of a virgin floodplain and upland forest in Wabash County, Illinois, Lindsey (4) reports *Quercus macrocarpa* and *Ulmus rubra* exclusive to the bottomland where they were 5th and 15th respectively in importance value. These two species dominate the interior of the Rush Woods. Although the stand is clearly dominated by *Fagus grandifolia* and *Acer saccharum,* the prevalence of the above species indicates a lowland phase of the *Fagus-Acer* climax. It is hazardous to assume that the Rush stand authentically reflects the species aggregation which occupied depressional areas in the presettlement forest; it well may, however, small isolated stands are subject to many influences outside the edaphic factor considered here.

It has been noted by many workers in Indiana (5, 6, 9, 10) that beech is decidedly more tolerant of poorly drained soils than is sugar maple. The tolerance spectrum for maple on the other hand extends beyond beech into xeric but well aerated soils (11). This can be seen in wide spread oak to maple transition stands in Indiana in which beech is not represented. The condition of aeration markedly alters *Fagus-Acer, Acer-Quercus* composition on soils within the same narrow climatic regime. However, recognition of drainage and aeration classes does not provide an explanation of how this edaphic factor is discriminatory to species involved. Oxygen-deficit is an obvious factor and may be the over-riding one. Kramer and Kozlowski (2) point out that very wet soils hinder the biological activity necessary for the decay release of nitrogen and other elements. In this connection, we observed densely developed ectotrophic mycorrhizas on beech roots in the Rush Woods. These were clearly more profuse than those of beech growing on better drained soils of the surrounding area. The ecological significance of the mycorrhizal relationship to species competition and forest composition is still poorly understood, i.e. whether they confer a nutrient advantage during competitive stages, or are more accurately seen as simply opportunizing on the photosynthetic excess of the chlorophyllous plant. Certainly, too little is known of the mechanisms and the extent to which various soil biota-root complexes arbitrate the availability of nutrients, moisture, etc. thereby modifying the general edaphic parameters used by community ecologists. There is little doubt, however, that beech enters into these interactions at suboptimum O_2 levels more successfully than either maple or tulip poplar.

There is a high prevalence of windthrown beech in the Rush Woods which results principally from decay of the shallow root systems (Plate

I-3, 4, 5). This may support the thesis of nitrogen tie-up. Nitrogen deficiency results in a species inability to adequately metabolize carbohydrates (2) which then accumulate in root tissues. These carbohydrate excesses may provide substrate for pathogens in addition to mycorrhizas and could allow normal symbionts to elaborate their metabolism to a pathogenic degree. There is apparently a concurrent decrease in the tree's vigor and disease resistance. The phytosociological result in the Rush Woods is an aspect of widespread disturbance with various stages of gap-replacement and the absence of the older and larger trees one normally expects in a virgin stand. In this way, windthrow frequently reduces the D_2 and D_3 figures for beech on these poorly drained, poorly aerated soils. There is a complementary increase in these parameters for sugar maple. Figure 1 contrasts the response of density, basal

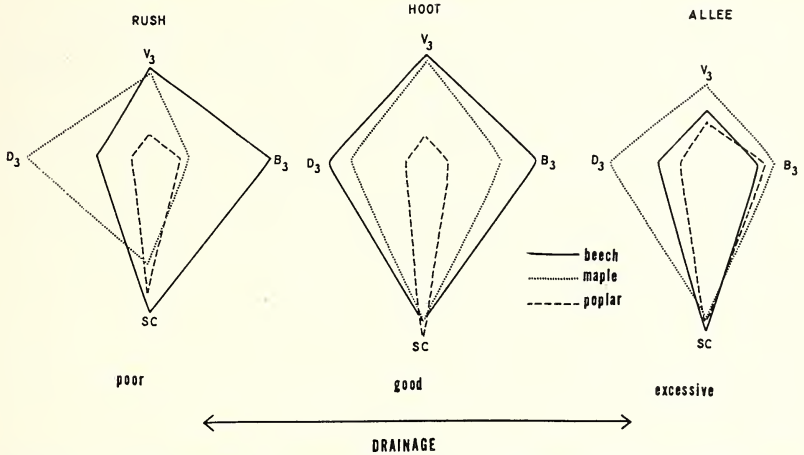

Figure 1. A comparison of the response to soil drainage of the relative stand attributes of dominant species in three virgin upland forests; Rush Woods, Montgomery Co., Hoot Woods, Owen Co., Allee Woods, Parke Co., Indiana. Attribute abbreviations: D_3, relative density; B_3, relative basal area; V_3, importance value; SC, maximum size class.

area, maximum sizeclass and importance values for beech, maple and tulip poplar in 3 Indiana stands of diverse drainage (7) (8).

In terms of future succession, it is interesting to speculate what species will replace *Ulmus rubra* and *U. americana* in the Rush Woods and elsewhere. It is apparent that there will be an extended period of crown disturbance in as much as vigorous elm saplings dominate the secondary growth under the dead elm (Plate I-2). Until the regrowth cycle (to disease susceptibility) of these young trees is diminished, their dense foliage and that of associated spicebush (*Lindera benzoin*) will eliminate intolerant species from the sere. This question of a replacement species for elm in wet phases of mesic forest will make the Rush Woods a particularly interesting stand to observe in subsequent years.

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SOIL SCIENCE

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Row Fertilization Effects on Potato Growth on Sandy and Organic Soils[1]

GERALD E. WILCOX, Purdue University

A certain optimum concentration of nutrients in the soil is required for maximum potato yields. An adjustment of the concentration of nutrients in soil must often be made by the application of fertilizer. This adjustment offers problems in both rate and placement of fertilizer for the best response. Lucas et al. (7) found that the application of 300 lbs of potassium on organic soil resulted in the highest yield of potato tubers, however, a treatment of 100 lbs of K_2O resulted in the highest yield of starch. Yield of starch should be of importance in determining proper fertilization methods.

Decreasing amounts of potassium in the band results in increased dry matter. Findlen (5) found that nitrogen, phosphorus and potassium fertilizer applications in bands at planting time of 0 and 60 pounds in factorial combinations had no important effect on chip color. However, the high rate of nitrogen and potassium application reduced chip yield. Most soils used for potato production need applications of N,P and K to maintain optimum growth and yields. Black and Cairns (2) reported that broadcast applications of nitrogen, phosphorus and potassium showed economic gains in yield without loss of quality. Lorenz, et al. (6) has reported the need for potassium fertilization in reducing black spot damage. Though potassium plays a significant role in potato nutrition and must be applied, it appears that it should not be present in high concentrations in the band application at planting time. Berger, et al. (1) found that phosphorus uptake was increased when potassium was broadcast in comparison to row application. Dunn & Rost (4) reported similar effects of potassium fertilization.

In this experiment the effect of potassium rates and materials on potato growth and quality was measured on sandy soils and organic soils.

Materials and Methods

The experiments were conducted in 1958 near Vincennes on Buckner sandy loam and Fox sandy and in 1960 and 1961 on Houghton muck at the Northern Indiana Muck Experiment Farm near Walkerton. Cultural practices for weed control and insect control were applied to all experiments during the growing season.

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1. Journal Paper No. 2246 Purdue University Agricultural Experiment Station, Lafayette, Indiana.

The Buckner sand loam was pH 5.8 and contained 120 pounds per acre P_2O_5 and 191 pounds per acre exchangeable K_2O while the Fox sand was pH 6.4 and contained 650 pounds per acre available P_2O_5 and 349 pounds per acre exchangeable K_2O as determined by the Purdue soil testing laboratory. Fertilizer treatments applied in 1958 are listed in table 1. Plots 12 x 36 feet, were replicated three times in a randomized

TABLE 1. Potato yields and specific gravity from various broadcast and row fertilizer treatments on sandy soils. 1958.

Treatments			Rate 5-10-15S in row			
Broadcast Pounds Per Acre			600 lbs/A		1200 lbs/A	
N	P	K	Yield	Sp. Gr.	Yield	Sp. Gr.
			bu/A		bu/A	
Buckner Sand Loam						
65	40	200	608	1.068	624	1.063
130	80	100	606	1.066	605	1.065
97.5	60	150	593	1.067	612	1.061
97.5	95	150	650	1.066	611	1.063
65	80	200	585	1.066	598	1.062
152	95	235	596	1.068	592	1.064
Fox Sand			584	1.064	598	1.059

block design. Thirty feet of the two center rows were harvested for yield. The broadcast fertilizer treatments, formulated from ammonium nitrate, treble super phosphate and muriate of potash, were applied before planting. Commercial 5-10-15, with the potassium derived from potassium sulfate, was used in the row. This was applied with an Iron Age planter at time of planting. Kennebec potatoes were planted the last week in March. The soil was irrigated on a regular schedule during June and July to provide sufficient moisture. The potatoes were harvested the last week in July.

The Muck soil was a well decomposed, finely divided, dark organic soil in which little or no organic matter could be identified as to origin. In 1960 the soil from the plot area tested pH 5.3 and contained 405 pounds per acre available P_2O_5 and 1260 pounds per acre exchangeable K_2O. Five treatments, as listed in table 2, were applied to Katahdin potatoes May 13, 1960. The yield and specific gravity of tubers were recorded when the potatoes were harvested October 14.

The 1961 experiment was conducted on a soil which tested pH 5.6, and contained 570 pounds per acre available P_2O_5 and 680 pounds per acre exchangeable K_2O. The treatments, listed in table 3, were placed in bands by an Iron Age planter. The plot was of a split plot design with six replications. Russet Burbank potatoes were planted May 5, 1961 and harvested October 10, 1961. Tissue samples of petiole and fully expanded leaves below the growing point on the main stem were collected on June 12. The samples were dried at 70° C, ground and analyzed for P, K, Ca and Mg.

Results

The fertility levels of the soils in all experiments were such that no significant yield response to fertilizer treatment was obtained.

In all cases (table 1) the increase from 600 to 1200 pounds per acre of 5-10-15 fertilizer in the row reduced the specific gravity of potatoes in 1958.

The effects of K rates and materials on specific gravity of potatoes produced on organic soils in 1960 are presented in table 2.

TABLE 2. Potato yield and specific gravity from various row fertilizer treatments on organic soil. 1960.

Treatment Rate/A Row Fertilizer Application			Yield	Specific
N	P	K	Per Acre	Gravity
	lbs		bu	
60	135	85[a]	730	1.067
72	125	120[b]	757	1.062
72	125	120[c]	758	1.065
72	0	120[c]	745	1.065
36	47	270[b]	751	1.060
LSD p = .05			N.S.	.0024

[a] K as KH_2PO_5
[b] K as KCl
[c] K as K_2SO_4

TABLE 3. Potato leaf composition and tuber yield and specific gravity from various K treatments on organic soil. 1961.

Treatment[a]				
K per acre row rate	Source	Leaf 6/12/61 Ca	Tuber Yield/A.	Specific Gravity
lbs		%	cwt	
0		.716	338	1.064
75	Cl	.875	299	1.064
	SO_4	.633	330	1.064
150	Cl	.833	316	1.062
	SO_4	.742	333	1.062
225	Cl	.950	298	1.062
	SO_4	.633	314	1.065
300	Cl	.842	288	1.062
	SO_4	.675	327	1.064
LSD p = .05		.138	21	.0014

[a] All plots received 44-104-0 in addition to the K treatments in the row.

Potatoes with a specific gravity of 1.067 were obtained from the application of 85 pounds K per acre as KH_2PO_4. The specific gravity of potatoes fertilized with 120 pounds per acre K as K_2SO_4 was 1.065. Specific gravity was significantly reduced by the application of 120 and 270 pounds K per acre as KCl. These treatments resulted in tubers with specific gravity of 1.062 and 1.060 respectively.

The results of the 1961 experiment are presented in table 3. Increasing the rate of K as KCl in the row decreased specific gravity .002 units at the 150 pound per acre rate. There was no further reduction as the K rate increased to 300 pounds per acre. K as K_2SO_4 applied in the row affected specific gravity only at the 150 pound per acre rate. The Ca composition of the leaves at the June 12 sample date was significantly higher for the KCl treatments than for the K_2SO_4 treatments.

Discussion

The fertilizer treatments did not visibly affect the growth characteristics of the plants during the growing season. The fertilizer effect on tuber specific gravity was greatest with the coarse textured soils, which are of lowest water holding capacities. The greater effect of the high rate of potassium in the row on specific gravity of potatoes grown on sandy soils was evidently due to effect on the growth rates of the potatoes which although not visible in the top growth had a measurable effect on dry matter production in the tubers.

At comparable K rates KCl had a greater effect on reduction of specific gravity than did K_2SO_4. The katahdin potato grown on organic soils was markedly affected by the potassium in the row at rates of 120 lbs and 270 lbs K in 1960 when applied as KCl. However, in 1961 the magnitude of effect of the potassium in the row on specific gravity of Russet Burbank potatoes was not great, although significant. Even at rates as high as 300 lbs K per acre in the row there was little reduction in specific gravity of the tubers.

The fact that the Ca composition of the tissue of the young potato plant was affected by the K salt applied suggests the possibility of a direct effect in the plant or in indirect effect due to changes in equilibrium composition of the soil solution around the fertilizer band. If the composition and the salt concentration in the soil solution about the band does not greatly affect the growth rate of potatoes on organic soil, the roots can evidently feed in other areas and not depend on the nutrition from the vicinity of the band. It may be anticipated that the seed piece-fertilizer band relationship would be a problem of greater magnitude in soils where a high proportion of the nutrition is derived from the fertilizer band.

Summary

Applications of fertilizers to high fertility soils did not give yield response but did affect quality. An increase in rate of 5-10-15 fertilizer row from 600 to 1200 pounds per acre reduced specific gravity an average of .004 units on sandy soils. This is equivalent to a reduction in about one per cent dry matter.

At comparable K rates in bands KCl reduced specific gravity of tubers more than the K_2SO_4 on organic soil.

Increasing amounts of K up to 300 lbs/acre applied to organic soils in band affected specific gravity slightly for Russet Burbank potatoes. The effect was greater for Katahdin potatoes.

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The Relationship of Soils and Fertilizers to the Nutrient Content of Apple Trees[1]

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Introduction

The observation by Liebig in 1840 that "crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it" has become the dominant concept in mineral nutrition. It, with modifications to include problems in nutrient availability and balance, has been the basis of chemical tests to establish the nutrient requirements of plants and soils. As an approach to problems in mineral nutrition, this philosophy has been very effective. Crop yields have been markedly increased and visible deficiencies have become rare.

However, as higher levels of fertility become more common, the limitations of this philosophy become more apparent. In fact, the ability to modify or improve the nutrient content of the plant by the application of fertilizer is becoming increasingly problematical. In this respect, some of our recent studies with fruit trees, more specifically with dwarfed apple trees, illustrate some of the areas in which knowledge is inadequate.

Leaf Composition and Tree Performance

For apple, one of the better, as well as more convenient tissues for establishing the nutrient condition of the tree is the foliage. The nutrient content of this tissue reflects the performance of tree sufficiently well to permit the establishment of "Standards" (2). Deviations from these standard values occur as is indicated in Table 1, but the amount of

TABLE 1. Standard leaf composition values for apples with the coefficients of variation and range for normal plants.*

Nutrient	"Standard"	Coefficient of Variation	Range expressed as a Percent of Average or Standard
N	2.33%	9.0	80-120
P	0.23%	43.9	39-236
K	1.53%	29.5	49-162
Ca	1.40%	30.6	56-158
Mg	0.41%	30.6	62-164
Mn	98 ppm	58.1	32-207
Fe	220 ppm	51.7	15-240
Cu	23 ppm	77.0	18-247
B	42 ppm	46.9	27-327

* After Kenworthy, A. L., 1961 (2).

1. Journal Paper No. 2262, Purdue University, Agricultural Experiment Station, Lafayette, Indiana.

deviation without changes in tree performance has been found to be remarkably small. This is particularly true considering the wide range in climatic soil and cultural conditions under which apples are grown.

The reliability of these "Standard leaf composition values" varies in practice both with the nutrient and the measure of tree performance. Such a test can be seen in Table 2. This data was obtained in a study

TABLE 2. Simple correlations between the nutrient content of the leaf and apple tree performance (3).

Measures of performance	Leaf Composition N	P	Ca	Mg	K
Tree Height	.28	.03	—.29	—.40	.57
Trunk Circumference	—.01	—.02	—.00	—.25	.36
Trunk Growth	.07	—.12	—.09	—.24	.40
Shoot Growth	.01	—.10	.10	—.24	.08
Number of Shoots	—.63	—.05	.54	.46	—.20
Number of Blossoms	—.55	—.48	.47	.56	—.32
Number of Fruits	—.48	—.40	.39	.44	—.19

Significance: 5% level r = .44
1% level r = .56

involving a group of trees which varied widely in growth and fruiting characteristics, as well as nutrient content. The level of all of the nutrients however, were within the optimum range. Of interest, is the fact that most of the various measures of growth recorded did not correlate well with the level of any single nutrient tested, N, P, K, Ca,

TABLE 3. Multiple correlations between various measures of tree performance and the nutrient content of the leaf expressed as interaction coefficients (1).

Measures of performance	Expression of Nutrient Composition* Linear	Linear and Interaction
	r=	r=
Tree height	.72	.95
Trunk growth	.52	.88
Shoot growth	.41	.78
Number of shoots	.69	.84
Number of blossoms	.77	.96
Number of fruit	.67	.96

* Linear = N + P + K + Ca + Mg
Interaction = NP + NK + NCa + NMg + PK + PCa + KCa + KMg + CaMg

or Mg, yet significant correlations were obtained between most of these nutrients and fruiting (4).

When, however, the total quantity of nutrients (N, P, K, Ca, and Mg) present in the leaves were correlated with tree performance the level of significance was appreciably improved (see Linear expression in Table 3). The level of correlation was further improved when the balance between these five nutrients was considered and expressed as an interaction (1).

Such results emphasize the need for a better understanding of leaf analysis data. Involved is more than simply the quantity of any one nutrient or any single measure of tree performance. The balance between nutrients appears to be, at least, as significant and may correlate better with more different measures of tree performance.

Tree Structure and Nutrient Composition of the Foliage

In contrast to most plants which are propagated from seed, apple trees can be rather complex structures involving two or more separate individuals grafted together. Such a method of constructing trees allows the use of materials which impart greater disease, insect, drought or cold resistance to the tree as well as modifying its habit of growth and fruiting. The top or foliage bearing portion of the tree is referred to as the *scion* and the root portion as the *rootstock*.

If a rather extensive portion of plant material is employed as a portion of the trunk, comprising a major portion of that trunk, it is referred to as a *bodystock*. If not, it is designated an *interstock*. Interstocks may be as long as 6 to 8 inches or as short as ½ inch depending upon its function.

While such a method of constructing a tree serves many useful purposes, it confounds the problem of correlating the nutrient composition of the foliage with soil tests and fertilizer response. Trees which vary in the number of graft components as well as in the variety of plant

TABLE 4. Influence of rootstock, interstock and bodystock on the nutrient content of the scion variety Jonathan, 1958 (5).

Interstock	Bodystock	Rootstock	Nutrient content of the foliage* Percent dry weight				
			N	P	K	Ca	Mg
		Western	2.64	.21	1.41	1.32	.41
		EM VII	—.32	—.04	—.04	—.46	—.11
		EM II	.36	—.03	.24	—.29	—.06
		EM I	.54	.00	—.09	—.12	.05
		EM XIII	—.06	.01	.15	.13	.02
	Virginia	Western	—.73	—.05	.08	.03	.16
	Hibernal	Western	.14	.05	—.04	—.16	.03
Clark	Virginia	Western	—.66	.02	—.22	—.34	.04
Clark	Hibernal	Western	—.19	.06	.16	—.04	—.10
L.S.D.	5%		.31	.04	.13	.19	.04
	1%		.46	.07	.16	.28	.07

* Expressed as differences from the standard, Jonathan/Western

material used as one of the components, can be associated with distinctly different leaf composition values (5). As is shown in Table 4, such differences can be seen with trees of the same scion variety, growing in the same orchard and therefore under similar soils and management. While differences between rootstocks might have been anticipated from studies in nutrient uptake, such would not explain the influence of the bodystock and interstock. Also of interest in this data is the fact that the direction or amount of change in nutrient composition is not typical of a given plant material. For example, Clark, as an interstock, was associated with depressing the influence of Virginia bodystocks on leaf N but was associated with the opposite effect with Hibernal. The influence of Clark on leaf K also varied, being associated with increasing leaf K in one combination and decreasing it in another.

The importance of stock-scion relations in mineral nutrition is further emphasized by the results of another study. This investigation attempted to relate changes in nutrient composition of the scion foliage with changes in plant materials used as rootstocks and interstocks (4). Under consideration also was the interaction of plant materials suggesting the influence of the physical presence of the graft union as well as various degrees of congeniality between plant materials.

According to the analysis of variance, changes in the variety employed as the scion resulted in greater variations in nutrient content than changes made in the other plant parts (Table 5). Changes in

TABLE 5. Relative influence of the scion, interstock and rootstock on the nutrient content of the scion foliage as indicated by the significance of the analysis of variance (4).

Source of Variance	Nutrient				
	N	P	K	Ca	Mg
Rootstock	ns	ns	*	ns	*
Interstock	**	**	**	*	**
Scion	**	**	**	**	**
Interaction of:					
Rootstock and Interstock	*	ns	ns	ns	ns
Rootstock and Scion	ns	ns	ns	ns	ns
Interstock and Scion	**	**	*	ns	**
Rootstock, Interstock and Scion	**	*	**	ns	ns

ns no significant correlation
* correlation significant at the 5% level
** correlation significant at the 1% level

rootstock caused the least amount of variation while the interstock was intermediate in its influence but more nearly resembling the amount of variation caused by the scion than by the rootstock. Any interactions which might have been present involving the rootstock were not associated with changes in nutrient content. However, the interaction of the interstock and scion varieties resulted in several highly significant variations.

The results of these experiments indicate that the role of each of the various portions of the plant in mineral nutrition is not fully understood. It suggests that their activity is more complex and more vital than is commonly depicted. The dominant influence of the stem and foliage bearing portions of the plant is particularly noteworthy and deserves further study.

Nutrient Supply and Composition of the Foliage

The use of foliar analyses to determine the nutrient requirement of the tree assumes that the nutrient content of the foliage is a true reflection of nutrient supply. It also assumes that modifying this supply, as with the addition of fertilizer, will result in a corresponding change in nutrient content of the tree.

In this respect, several studies which have attempted to correlate nutrient supply with nutrient content are of interest. Because of the question of differences in availability of nutrients to different rootstocks, a comparison was made between the K content of the soil and that of the foliage of twelve stock-scion combination (3). Soil samples were taken at the outer edge or drip line of the trees and a composite made between the 4 to 24 inch depths. As shown in Table 6, little

TABLE 6. Relationship between the availability of K in the soil and the K content in the foliage of various stock-scion combinations (3).

	Ratio Leaf K (%) to Available Soil K (me)			
Scion Variety	Western	EM II	EM VII	Mean
Golden Delicious	1.34	1.54	1.38	1.42
Delicious	1.38	1.97	1.55	1.63
Jonathan	1.28	1.44	1.19	1.30
Rome	.88	1.86	1.30	1.48
	1.23	1.70	1.37	

relationship was noted between soil and leaf K although the soils tested, ranged from medium to high in available K. Further, differences between scion varieties were almost as great as between rootstocks.

A similar lack of association between nutrient supply and nutrient content of the foliage was noted in a long term fertilizer trial (3). Four scion varieties placed in combination with three different rootstocks were fertilized differentially with N, NP, NPK, N-K and N-KMg over a four year period as shown in Table 7. Leaf samples taken from these combinations and treatment were not significantly different in any of the nutrients tested nor was there any great variation between trees.

In still another experiment, differences in the availability of nutrients to the root were eliminated by growing trees in sand culture (1). The six rootstocks used were all grafted to the same scion variety to facilitate comparison. A modified Hoagland's nutrient solution was supplied to trees at ½rd, 1 and 3x standard strengths. As shown in Table 8, while there was a tendency for the nutrient content of the

TABLE 7. Influence of four years of fertilizer treatment upon the nutrient content of scion foliage (3).*

Treatment	Rootstock	Nutrient Content Percent Dry Weight				
		N-	P	E	Ca	Mg
N—	EM II	2.6	.22	1.4	1.2	.40
	EM VII	2.6	.21	1.4	1.2	.39
	Western	2.7	.22	1.4	1.3	.40
NP—	EM II	2.7	.21	1.5	1.1	.39
	EM VII	2.6	.22	1.4	1.2	.42
	Western	2.9	.23	1.3	1.2	.38
NPK	EM II	2.7	.22	1.6	1.1	.37
	EM VII	2.6	.23	1.5	1.2	.38
	Western	2.8	.24	1.5	1.3	.39
N-K	EM II	2.5	.23	1.6	1.2	.38
	EM VII	2.6	.22	1.6	1.2	.38
	Western	2.9	.23	1.4	1.2	.40
N-KMg	EM II	2.7	.22	1.6	1.1	.37
	EM VII	2.5	.22	1.6	1.2	.39
	Western	2.8	.23	1.5	1.2	.37
	CV	3.5%	.74%	2.4%	1.2%	.67%

* Mean of Delicious, Golden Delicious, Jonathan and Rome varieties. Annual rate of fertilization per tree: N-0.51 lb., P-2.5 lb., K-0.9 lb., Mg-0.5 lb.

TABLE 8. Influence of nutrient solution concentration on the nutrient content of Delicious foliage expressed as the difference in per cent dry weight (1).

Rootstock	Difference in Nutrient Content*				
	N	P	K	Ca	Mg
EM XI	.59	.03	.82	—.23	—.06
MM 106	.17	.02	.95	.19	.02
EM II	.35	.02	.48	—.27	—.04
EM I	.00	—.04	.89	—.04	—.08
EM XIII	.43	.01	.40	.04	.04
Western	.25	—.02	.88	.07	.08
Mean	.30	.00	.73	—.04	—.01

* Difference between trees grown in 1/3rd and 3x standard Hoagland's nutrient solution.

foliage to be higher in the more concentrated nutrient solution, only N and K were significantly increased. Considering the fact that one solution was nine times as concentrated as the other, such changes must be considered remarkably small. Further, the response varied with each of the nutrients thereby creating in the leaves an entirely different condition of balance between nutrients.

Discussion and Conclusions

The results of this series of studies indicate that at near optimum levels of nutrition, tree performance is not necessarily related to the quantity of N, P, K, Ca or Mg in the foliage. Only when all five of these major nutrients were considered and expressed empirically to reflect the balance between them were the correlations with tree performance highly significant. Similarly, when trees were constructed employing different combinations of rootstock, bodystock, interstocks, and scions, each combination was found to develop leaf composition values which were dissimilar and unrelated to either nutrient availability or supply.

It can also be suggested from these results that soil and plant analyses are of primary use in establishing mineral deficiencies. At higher levels of fertility, their value is establishing nutrient requirements is limited.

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Nutritional Survey of Indiana Apple Orchards Utilizing Foliar Analysis as the Diagnostic Tool[1]

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Foliar analysis has been used in orchard fertility investigations for many years. As leaf analysis methods have been developed for fruit trees and sampling methods standardized, optimum leaf concentration ranges and critical leaf levels have been determined. In recent years fruit orchard surveys, utilizing leaf analysis as the diagnostic tool, have been performed to determine the nutritional status of these orchards, to diagnose nutritional disorders, to determine true nutrient requirements and to aid in developing orchard fertilization programs (1, 2, 4, 5, 7, 8, 9).

Methods and Materials

In 1961 and 1962 a survey was made in Indiana using both foliar analysis and soil tests to evaluate the general nutritional condition of Indiana apple orchards. Twenty orchardists participated in this survey and 40 samples of leaves were collected.

Leaves were collected from the mid-section of current season growth located five to seven feet above ground level. Leaves collected were free of insect, disease and mechanical injury. Only one leaf and petiole was removed from a shoot and only five to eight leaves from any tree. Eight to ten trees were sampled and the leaves composited. Each sample, consisting of 60 to 100 leaves, was placed in a kraft paper bag and forwarded to the Michigan State University Plant Analysis Laboratory. Leaves were analyzed for nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron, copper, boron, zinc and molybdenum.

Soil samples taken from a 6 to 10 inch depth, were collected from leaf-sampled trees. Samples were taken at the tree drip line. Soil

TABLE 1. Standard Leaf Composition Values for Apple Trees and Normal Range in Leaf Composition Values Under Michigan Conditions (6)

Element	Standard	Normal Range
N - %	2.33	1.60 - 2.49
P - %	.23	.155 - .295
K - %	1.53	1.16 - 1.90
Ca - %	1.40	1.06 - 1.70
Mg - %	.41	.31 - .49
Mn - ppm	98	59 - 137
Fe - ppm	220	141 - 302
Cu - ppm	23	6.4 - 40
B - ppm	42	28.6 - 55
Zn - ppm	30	23 - 37

1. Journal Paper No. 2242 of the Purdue University Agricultural Experiment Station, Lafayette, Indiana.

samples were tested by Purdue Soil Testing Laboratory for pH, available phosphate and available potash.

Results

Kenworthy (6) has proposed standard leaf composition values for common macro- and minor elements of fruit trees. These values are the levels of nutritional content in the foliage associated with good horticultural performance. These values plus a "normal range" in nutritional content for each element for apple are shown in Table 1.

Analyses of the leaf samples revealed variations between samples for each element. The means and ranges for each element and the dis-

TABLE 2. Means and Ranges in Leaf Composition Values for 1961 and 1962 Indiana Leaf Samples and Distribution of Leaf Samples Within Low, Normal or High Range for Nutritional Elements As Proposed by Kenworthy (6)

			Sample Distribution		
Element	Mean	Range	Low	Normal	High
Nitrogen %					
1961	2.03	1.53 - 2.74	1	38	1
1962	2.02	1.44 - 2.46	4	36	0
Phosphorus %					
1961	.184	.128 - .336	10	29	1
1962	.174	.112 - .282	21	19	0
Potassium %					
1961	1.33	.84 - 1.82	7	32	1
1962	1.19	.86 - 1.66	19	21	0
Calcium %					
1961	1.09	.70 - 1.82	21	18	1
1962	1.01	.43 - 1.72	21	18	1
Magnesium %					
1961	.32	.20 - .48	14	26	0
1962	.30	.16 - .40	19	21	0
Manganese ppm					
1961	169	54 - 674	4	32	14
1962	132	26 - 528	4	26	10
Boron ppm					
1961	33.3	26.0 - 42.8	7	33	0
1962	33.5	13.5 - 49.6	9	31	0
Iron ppm					
1961	167	98 - 259	13	27	0
1962	105	50 - 163	35	5	0
Copper ppm					
1962	11.3	6.0 - 16.6	1	39	0
Zinc ppm					
1962	50.1	13 - 140	8	12	20
Molybdenum ppm					
1962	4.7	2.2 - 8.2			

tribution of these samples, either below, within or above the indicated normal range, for respective elements is shown in Table 2.

Leaf potassium content was low in some samples. Likewise 52 percent of the samples were low in calcium. Leaves analyzed in 1961 revealed 35 percent of the sample to be low in magnesium, while 48 percent of the samples collected in 1962 were low in magnesium. Several leaf samples had a low leaf boron content.

Leaf manganese was high in 35 percent of the 1961 samples and in 25 percent of the 1962 leaf samples. Likewise 50 percent of the samples analyzed in 1962 had a high leaf zinc content.

The distribution of pH values for the soil samples is presented in Table 3. Seventy-nine percent of the samples collected in 1961 tested pH 5.5 or lower. Seventy-four percent of the soil samples tested pH 5.5 or less in 1962.

Table 4 shows the distribution of available potash values for the

TABLE 3. Distribution of Soil pH Values for Indiana Orchard Soil Samples

	Number of Samples	
pH Range	1961	1962
4.5 - 5.0	12	13
5.1 - 5.5	19	15
5.6 - 6.0	4	6
6.1 - 6.5	3	3
6.6 +	1	1

TABLE 4. Distribution of Available Potash Values in Indiana Orchard Soil Samples

	Number of Samples	
Potash - lbs/A	1961	1962
0 - 100 (very low)	3	5
101 - 180 (low)	22	22
181 - 250 (medium)	6	6
251 - 375 (high)	5	5
376 + (very high)	4	—

soil samples. Sixty-two percent of the soil samples had a soil test below the medium level in 1961 and 72 percent tested similarly in 1962.

The distribution of available phosphate values for the soil samples are illustrated in Table 5. The sample distribution was similar both years with slightly over 50 percent of the samples testing less than 100 pounds available phosphate per acre.

TABLE 5. Distribution of Available Phosphate Values in Indiana Orchard Soil Samples

Phosphate - lbs/A	Number of Samples 1961	1962
0 - 40 (very low)	10	12
41 - 100 (low)	11	9
101 - 180 (medium)	7	8
181 - 300 (high)	6	6
301 + (very high)	5	3

Discussion of Results

An increase in leaf nitrogen content would be desirable in several orchards. Excessive nitrogen usage in Indiana orchards was not revealed in this survey. Leaf analysis indicate no critical shortage of nitrogen to occur. Most growers are making annual applications of nitrogen which contributes to the favorable status of this nutrient element.

Some sampled orchards would benefit from applications of potash. The percentage of leaf samples low in potassium was much greater in 1962. This could be a result of slightly earlier leaf sampling, especially since the growing season began slightly later than in 1961. The summer growing season was drier in 1962 and Hibbard and Nour (3) found lower leaf potassium levels when trees were grown under moisture stress. A majority of the soil samples also indicated applications of potassium should be beneficial to the trees.

Leaf calcium levels were similar both years and results indicate a majority of orchards should benefit from lime applications. Less than 13 percent of the soil samples tested pH 6.0 or above. Indiana orchardists are advised to maintain orchard soil pH above 6.0. Ammonium fertilizers and sulfur sprays probably contribute to the acid soil conditions.

The low leaf magnesium levels probably can be related to soil pH. Dolomitic limestone applications would correct magnesium shortage and calcium need. Applications of potassium to orchards where leaf analysis suggested a need, without correcting the magnesium needs could result in severe magnesium deficiency.

Excess levels of leaf manganese were present in 25 percent of the samples. Low soil pH and applications of certain fungicides in disease control programs would produce this condition.

Leaf boron levels were rather satisfactory. Applications of boron would be beneficial in a few sites and these sites were generally located on light soil.

The high leaf zinc levels are probably related to fungicidal programs utilized by orchardists.

Summary

Forty leaf samples were collected in 20 orchards in 1961 and again in 1962 and analyzed for nutrient element content. Soil samples were also collected.

Leaf analysis were compared with nutrient values proposed by Kenworthy for apples. Nitrogen levels were fairly satisfactory for most orchards. Some orchards required applications of potash. Fifty percent of the leaf samples were low in calcium. Likewise a shortage of magnesium was indicated in 35 percent of the leaf samples. About 20 percent of the samples indicate a need for boron.

High leaf manganese levels were observed in about 25 percent of the samples. Leaf zinc values were high in 50 percent of the samples collected in 1962.

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Determining Evapotranspiration Rates and Soil Moisture Levels With Climatological Data[1]

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Evapotranspiration is the term used to designate the process of water movement in the vapor state from the earth's surface to the atmosphere. Hydrologically it includes evaporation from open water surfaces, the surface soil, and transpiration by plants. It does not include the water moved downward out of the root zone.

Evapotranspiration is primarily an energy controlled process. However, it is influenced by soil, plant and atmospheric factors which govern the absorption and distribution of energy at evaporating surfaces, and by the flux of liquid water to, and water vapor from such surfaces.

In a previous paper (7), with the hydrologic equation on long term precipitation and runoff records, the author determined the average annual evapotranspiration for all the watersheds of Indiana. He showed that the average evapotranspiration for the state was about 27 inches per year. This is approximately 70 percent of the annual precipitation. The influence of evapotranspiration and precipitation characteristics on soil moisture deficits was also noted, and in turn, the influence of such moisture deficits on plant growth responses.

Thus, agriculturally, the soil moisture deficit during the growing season is of extreme economic importance. Soil moisture can be determined by taking samples; however this is time consuming and expensive if done on an intensive scale. It would be helpful to have a simple means of estimating or predicting the soil moisture condition at any geographic location, or for a general area. Since atmospheric conditions have such a dominant influence on the rate of evaporation, relating any one or several of the atmospheric parameters to evapotranspiration and in turn to soil moisture deficit has obvious possibilities. This is especially true if measurements can be made in the normal Weather Bureau station network. Empirical equations using mean air temperature as a basis for evaluating the evapotranspiration rate have been developed by Blaney-Criddle (1), Thornthwaite (6), and Holdridge (3), among others. Evaporimeter devices such as the Class A Evaporation Pan, Livingston atmometer, Bellani Plates, and Piche blotting paper have also been used for estimating evapotranspiration. The vapor flow, and surface energy balance methods offer good physical basis for making fairly accurate estimations of evapotranspiration, however, the complicated instrumentation and calculations make these latter methods less practical. Penman (4) has developed a formula which includes net radiation, saturation deficit, and wind speed which has proven quite successful, but has the

1. Contribution from Purdue University, Agricultural Experiment Station, Journal Paper No. 2247. Part of thesis submitted by senior author in partial fulfillment of the requirements for the Master of Science Degree.

same drawback of tedious computations. Tanner (5) has made a simple relationship of net radiation to evapotranspiration which in some areas may be adequate. The purpose of our study was to determine the adaptability of the more promising methods now in use for estimating evapotranspiration under the climatic regime that prevails in Indiana. Also each of the climatic parameters measured were examined as to their relationship with the evapotranspiration process.

The experimental data was taken on one crop, corn, for the period July 11 to September 5, 1958 at the Purdue Sand Experimental field near Culver, Indiana. The soil type is a Coloma loamy sand which is excessively drained, and has low available water retaining characteristics. Daily evapotranspiration was determined by taking daily soil samples and measuring the change in moisture gravimetrically. This method has obvious limitations, but a large number of samples were taken to reduce the sampling error. An official weather observation station is located on the field and the climatic measurements used for the study included precipitation, maximum and minimum air temperatures, relative humidity, wind speed at 2 meters above the ground surface, evaporation from a U. S. Weather Bureau Standard Class A pan, and evaporation from a black and a white Livingston Atmometer. Net radiation was calculated from a formula given by Penman (4).

The daily water use ranged from 0.07 to 0.32 inches per day with the maximum occurring on August 12. For a seven day period, the maximum average use rate observed was 0.23 inches per day, which occurred the second week of August when the corn was in the tasseling stage. The overall seasonal average was 0.16 inches per day.

Comparisons are made of the measured daily water use with the Blaney-Criddle, the Thornthwaite, and the Penman formulas; the difference between black and white Livingston atmometers, and the Class A Pan. Correlations were also made with the climatic factors of net radiation, mean daily temperature, relative humidity, mean daily wind velocity in miles per hour, and actual sunshine hours. The correlation coefficients of these are given in Table 1.

Of the climatic factors, net radiation showed the highest correlation with water use rates. This fits nicely with the theoretical concept that evapotranspiration is primarily a result of the energy balance occurring on the earth's surface. Sunshine hours are also fairly well correlated with daily water use. This may be reflected by the high correlation of sunshine hours and net radiation, which was 0.71.

The factors of relative humidity, wind velocity and temperature are poorly correlated with the measured water use. The high relative humidity and frequent cloudiness that prevailed during most of the study period undoubtedly reduced the correlation of temperature with water use rates. A critical examination of the original climatogical data reveals that the negative correlation of wind velocity with evapotranspiration was due to the interaction between climatic factors. The data showed that when wind velocity increased water use rates decreased because of cloudiness, low net radiant energy, and high humidity. These factors overshadowed the generally negligible effects of wind velocity.

TABLE 1. Correlations of the Measured Daily Water use with the Climatic Factors; With the Estimated Daily Evapotranspiration by Formula; and that Estimated with Evaporimeter.

	Correlation Coefficient (r)
Climatic Factor	
Net radiation	0.77
Mean daily temperature °F	0.28
Relative humidity, percent	—0.29
Mean daily wind velocity, mi/hr.	—0.16
Actual sunshine, hr/day	0.54
Formulas	
Blaney-Criddle	0.11
Thornthwaite	0.25
Penman	0.92
Evaporimeters	
Livingston atmometers	0.82
Weather Bureau Class A Pan	0.47

The two empirical equations, Blaney-Criddle and Thornthwaite, which use temperature as the primary basis for estimating evapotranspiration are both poorly correlated with daily water use. It is interesting to note that the correlation between computed water use by the Thornthwaite equation and measured water use ($r=0.25$) is almost the same as that between daily mean temperature and observed water use rates ($r=0.28$). Also if a plot is made of the measured daily water use and those estimated by the Thornthwaite formula early in the season the estimated rates tend to be higher than the measured, and during the latter part of the season the estimated tend to be lower than the measured. This can be explained by the energy balance as early in the season the energy flux is into the soil, and later in the season energy flux is out of the soil. Also during the early part of the season the corn crop may not have had a complete canopy, thus tending to lower the actual rate.

An evaporimeter is an integrator of the same climatic factors as those involving evapotranspiration. The difference in evaporation between a black and a white Livingston atmometer was found to be well correlated with measured water use, $r = 0.82$. This method has been reported by Halkias et al. (2). Because of the simplicity and low cost, this method shows considerable promise. The correlation of the Class A Pan and measured water use was not as high as other workers have reported in the literature. The advantage of this method is that many weather stations make routine pan evaporation measurements.

Finally, from the table 1 the high correlation between the measured water use and that computed by the Penman formula should be noted (Fig. 1). This again likely reflects the close association between

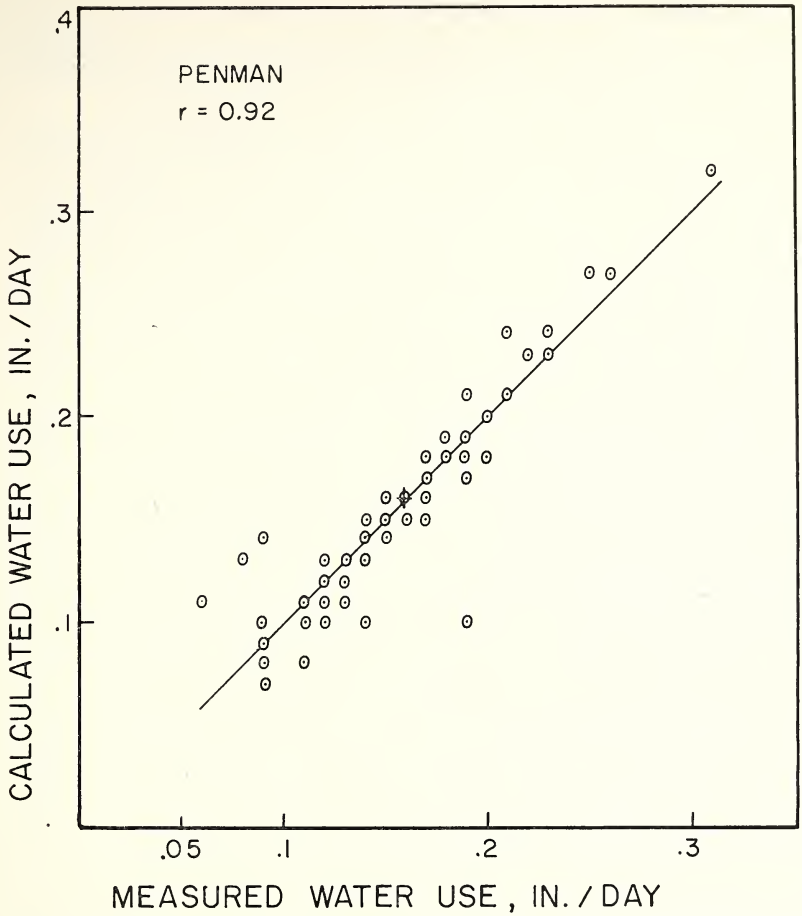

Figure 1. Relation of the Daily Evapotranspiration Rates Estimated by the Penman Formula to the Measured Daily Water Use Rates.

available energy and evapotranspiration, since the net radiation term has a prominent part in the equation. If net radiation data is available, solution of Penman's formula is relatively simple. However, if it must be computed, the equation is very complicated and time consuming. The energy balance approach is very promising; however, it is not likely to be generally adopted as a prediction technique unless net radiation measurements become more widely available and the information put on computer programs for computation.

It would be expected that the correlation coefficients of these various methods for estimating evapotranspiration and the measured water use would be greater as the time interval was increased. When weekly rates were compared, the coefficients were higher for the Livingston atmometers, and the Penman formula, but decreased for the Thornth-

waite, Blaney-Criddle, and the Class A Pan. However, it was interesting to note that the estimated daily water use rate averaged for the period July 11 to September 5 was 0.16 inches for all the methods which was identical to the measured average.

The results of the study indicated that if reasonably precise estimates of evapotranspiration are to be made over short periods of time, some measurement of radiation should definitely be considered. The evaporimeter has definite limitations, however it indirectly involves radiation, and because of its simplicity will receive future consideration. Any prediction formula relying mainly on temperature were of little value for estimating on a daily or weekly basis, however, when considering a seasonal water use was the same as the measured. This can be reasoned from the fact that temperature is a conservative parameter.

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The Effect of High Moisture Content at the Time of Soil Sample Preparation Upon Purdue Soil Test Values[1]

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In North Central regional potassium studies, Barber et al. (1) found that drying the soil, particularly the 18-24 inch depth samples, usually increased the exchangeable potassium and the potassium available to the plant. This did not appear to be true for the sixteen Indiana samples taken at 0-6 inch depth. Since many soil samples received in the Purdue Soil Testing Laboratory are from eroded fields, differences in available potassium related to the preparation and testing of moist samples from eroded fields may be important. This is particularly true in the spring when many samples are received in a moist condition. Since drying these samples takes additional time, there is a tendency to prepare the samples and test them as soon as they can be crushed and screened. It is also possible that soil sample preparation and testing when moist may alter pH and available phosphorus test values in the Purdue procedure.

The main purpose of this experiment was to determine whether moist rather than dry soil sample preparation and testing would change Purdue soil test values.

Methods

In Experiment I and Experiment II, 31 moist soil samples received from farmers were crushed and screened when moist and tested soon thereafter. Crushing and screening were done with a soil grinder with a 10-mesh screen. This grinder with two electrically powered metal rollers, was manufactured by the Hinkle Machine Shop, Lincoln, Nebraska. Soil tests used were those by Spain and White (2, 3) which are routinely used in the Purdue Soil Testing Laboratory.

In Experiment III, 101 previously crushed, screened, and air-dried soil samples received from farmers were riffled and separated into four subsamples. Two of these four subsamples were allowed to dry at room temperature until they were recrushed and rescreened. The other two subsamples were completely soaked with water and allowed to dry at room temperature. They were then recrushed and rescreened when just dry enough to go through the soil crusher without making a mud roll. Moisture in these samples ranged from 8.69% to 15.7% by weight. The air-dry subsamples which were not soaked with water had an average of 1.88% moisture.

After they were recrushed and rescreened, all subsamples were tested for available potassium with the same procedures used in experiments I and II.

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2. The author acknowledges the help of Mrs. Ann Malsbary, Mrs. Mary Linville, Mrs. Berin Keskin and Mr. Robert Ruggles.

Results and Discussion

The preparation and testing of moist, as compared with dry soil samples, did not appear to result in different values for soil pH and available phosphorus (Table 1). In the first two experiments there was some indication of higher potassium tests on the moist than on the air-dry samples. This is the reverse of the relationship reported by Barber et al. (1).

In Experiment III, the dry subsamples tested higher in available potassium than did the moist subsamples (Table 1). In experiments I

TABLE 1. Influence of moist crushing and screening on Purdue soil test values.

Experiment	No. Samples	pH		Available Phosphorus lbs. per A. of P		Available Potassium lbs. per A. of K	
		Moist	Dry	Moist	Dry	Moist	Dry
I	19	6.08	6.04	45	47	126	119
II	12	6.16	6.14	36	33	114	100
III	101	—	—	—	—	144	161

and II the moist samples were prepared, tested, air-dried, and retested without further preparation. This may have resulted in larger aggregates with less total surface and lower potassium test values in the air-dry samples. In Experiment III, subsamples were either (a) soaked, partially dried, prepared, and tested, or (b) air-dried, prepared, and tested. It was easily observed that the samples prepared and tested moist had larger aggregates than the air-dry subsamples. Also, the samples prepared and tested moist had an average potassium test value of 17 pounds per acre or 11% lower than those prepared and tested when air-dry. The lower potassium test appeared to be the result of

TABLE 2. Influence of moist crushing and screening on Purdue soil test values for potassium.

Texture	No. Samples	Potassium Test			t Test	Probability
		Increased	Decreased	Same		
Silty clay loam	5	0	5	0	2.97	.05 or less
Silt loam	76	8	68	0	5.92	.01 or less
Loam	14	3	11	0	2.29	.05 or less
Sandy loam	6	1	3	2	2.04	.10 or less
All samples	101	12	87	2	6.83	.01 or less

less soil surface for the action of the chemicals in soil with larger aggregates. Even though these data agree with much previously reported research in which drying increased potassium test values, there is considerable question about whether or not the reasons for the differences are the same.

Moist preparation and testing for potash appeared to result in lower potassium test values in a higher percentage of cases in silty clay loams and silt loams than in loams and sandy loams (Table 2). Decreases in potassium test values due to moist preparation and testing were significant at the 95 to 5 or higher level of probability in all textures except sandy loams. Hence, it appears that all soil samples received by the Purdue Soil Testing Laboratory should be completely air-dried before being prepared for testing. Texture is not determined until samples are crushed and screened in preparation for testing.

Summary

In experiments I and II with 31 soil samples, drying did not appear to change Purdue soil test values for pH and available phosphorus, but it did appear to decrease available potassium test values.

In Experiment III with 101 soil samples, moist subsamples tested an average of 17 pounds per acre lower in available potassium than the air-dried subsamples. Moist preparation resulted in lower available potassium test values more frequently in silty clay loams and silt loams than in loams and sandy loams. The lower available potassium test values with the moist subsamples appeared to be related to decreased soil surface because of larger soil aggregates.

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Pot Studies Indicate Need of Fertilization in Reforestation of Abandoned Cropland in Southern Indiana

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Planted hardwoods generally survive and grow poorly on abandoned farmland in southern Indiana. To devise methods for successful reforestation on such sites it is necessary to understand the underlying causes of failure. Various reasons for poor results have been suggested. However, the relations of specific physical, chemical, and biotic soil factors to tree growth have not been completely explained.

Recent studies (1) show that tree seedlings grown in pots of undisturbed soil taken from under various plant cover types could be used as a bio-assay to demonstrate gross differences in site quality. In natural forest soil, 12-week-old yellow-poplar (*Liriodendron tulipifera* L.) seedlings averaged 9.7 grams (green weight), while in soil from an abandoned field in weeds and grass, seedlings averaged only 2.9 grams.

Since seedling growth differed sharply in soils from under the various cover types, the next step was to find out how the soils differed. Subsequent study shows good correlation of yellow-poplar seedling growth with pore volume, bulk density, and organic matter content of the soil for all covers studied except black locust (*Robinia pseudoacacia* L.). Despite the poor physical condition of the soil under the black locust plantation, yellow-poplar seedlings grew almost as fast as those on natural forest soil.

Nutrient analysis showed that available phosphorus was highest in the locust soil, but all soils rated very low. With this information it was decided to study the response of pot-grown seedlings to applications of nitrogen, phosphorus, and potassium in soil supporting four different cover types. Black locust and tomato were used as the study species.

Study Area and Methods

The soils studied came from the Paoli Experimental Forest, Orange County, Indiana. All sites are on a single, broad ridge, and all except the forest site are part of a single abandoned field. The field varies slightly in topography and degree of erosion; consequently, there are inherent differences in soil properties among the selected sites. Mechanical analysis of the A and B horizons using the Bouyoucos Hydrometer method showed slight to moderate differences in the amounts of sand, silt, and clay among the four sites.

The sites are on unglaciated sandstone-shale soils of the Zanesville and Tilsit series. These are residual soils overlain with wind-deposited material. Tilsit silt loam occurs on broad, flat, upland ridges and de-

1. Journal Paper No. 2238, Purdue University Agricultural Experiment Station. The authors express their appreciation of aid to F. Bryan Clark of the U. S. Forest Service and M. L. Giskin, a Purdue Graduate Student.

velops from loess deposits ranging from 40 to 60 inches thick. A fragipan begins at about 24 inches causing poor internal drainage. Zanesville silt loam is similar to Tilsit but the pan begins at about 32 inches and internal drainage is better. This soil type is found on ridges and hillsides with slopes up to about 15 percent.

Site 1 supports a second-growth, mixed-hardwood forest on a Zanesville silt loam on a 10 percent slope. Internal and surface drainage conditions are good. The present stand has a basal area[2] of 143 square feet per acre.

Site 2 supports a 23-year-old shortleaf pine (*Pinus echinata* Mill.) plantation on Zanesville silt loam. This site is on a 4 percent slope and the fragipan begins at 33 inches. Internal and surface drainage are good. The stand basal area is 137 square feet per acre.

Site 3 supports a 23-year-old black locust plantation on an eroded portion of the field. The soil type is Zanesville silt loam on a 9 percent slope. The A horizon and part of the B horizon have been eroded and a firm fragipan begins at 22 inches. Under the present vegetation a new A horizon is beginning to develop. Basal area is 68 square feet per acre.

Site 4 is a part of the field presently supporting grasses and sedges. The soil is Tilsit silt loam on a 5 percent slope. A fragipan begins at 21 inches creating imperfect drainage.

Chemical tests for plant nutrient availability in the 0- to 3-inch and 3- to 6-inch zones of each site were made by the Purdue Soil Testing Laboratory. These tests showed that potassium ranged from "medium" to "very low," while phosphorus was "very low" in all cases (table 1), according to the scale used for agricultural crops.

TABLE 1. Phosphorus and potassium in 0- to 3-inch and 3- to 6-inch layers of soil

(In pounds per acre)

Plant cover	P_2O_5 Layer (inches) 0-3	P_2O_5 Layer (inches) 3-6	K_2O Layer (inches) 0-3	K_2O Layer (inches) 3-5
1. Mixed-hardwood forest	10	10	200	180
2. Pine plantation	10	10	160	90
3. Locust plantation	20	10	200	125
4. Abandoned field	10	10	110	70

Soil from the A and B horizons of the natural forest, pine plantation, and abandoned field was individually sampled, thoroughly mixed, and potted. In the locust plantation, samples were collected from the developing A horizon and from the B horizon. Tomato was planted in three replications on A- and B-horizon soil from all sites and black locust was planted in two replications on A-horizon soil from all sites. Nutrient

2. Basal area is the cross-sectional area of the tree stems at 4½ feet above ground in square feet per acre, and is used as a measure of stand density.

combinations of N-P-K, N-P, N-K, and P-K were compared with an unfertilized control. Application rates were 400 pounds of actual nitrogen, 200 pounds of actual phosphorus, and 200 pounds of actual potassium per acre. After 12 weeks' growth in a greenhouse the stems and leaves were oven-dried and weighed. Differences due to fertilizers and sites were compared by analysis of variance.

Results and Discussion

Both locust and tomato seedlings grew best when phosphorus was added to the soil in combination with nitrogen and potassium (Fig. 1a).

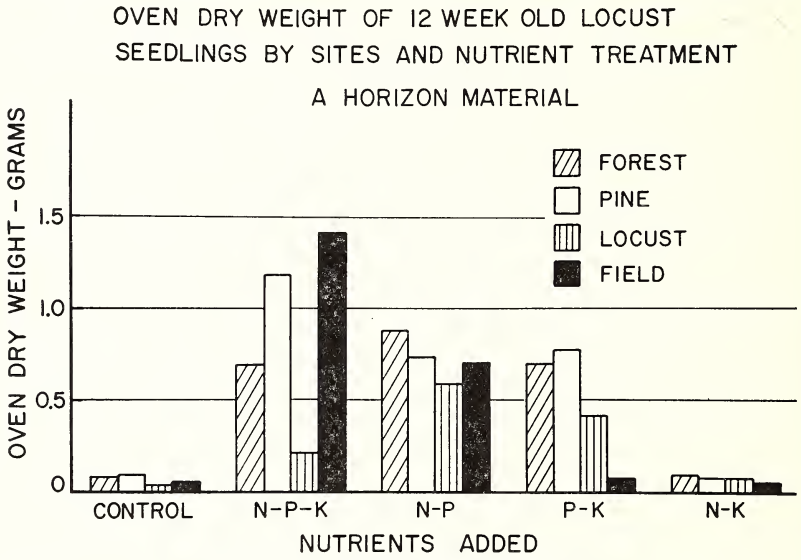

Figure 1a. Locust on A-horizon soil.

When phosphorus was omitted from the treatments there was no increase in growth over unfertilized plants. Generally, the addition of N-P-K yielded the best growth, followed by the N-P, P-K, and N-K treatments. Differences among fertilizer treatments were statistically significant at the 1 percent level. There was no consistent difference in growth due to site. The poor growth of the N-K treatment demonstrates that phosphorus is the main nutrient limiting growth of locust and tomato seedlings on the sites studied. Plants grew better with the N-P treatment than with the P-K treatment. This indicates that nitrogen may be slightly more important than potassium. Tomato plants proved to be a more sensitive indicator of phosphorus deficiencies than locust plants.

Fertilized tomato plants grew better on A-horizon soil than on B-horizon soil. This difference is likely due to higher original fertility and better physical conditions. Relative growth differences due to fertilizer treatments were greater on B-horizon soil than on A-horizon soil (Fig. 1b and 1c). This shows that nitrogen and potassium deficiencies are more critical in the B horizon than in the A horizon. On abandoned

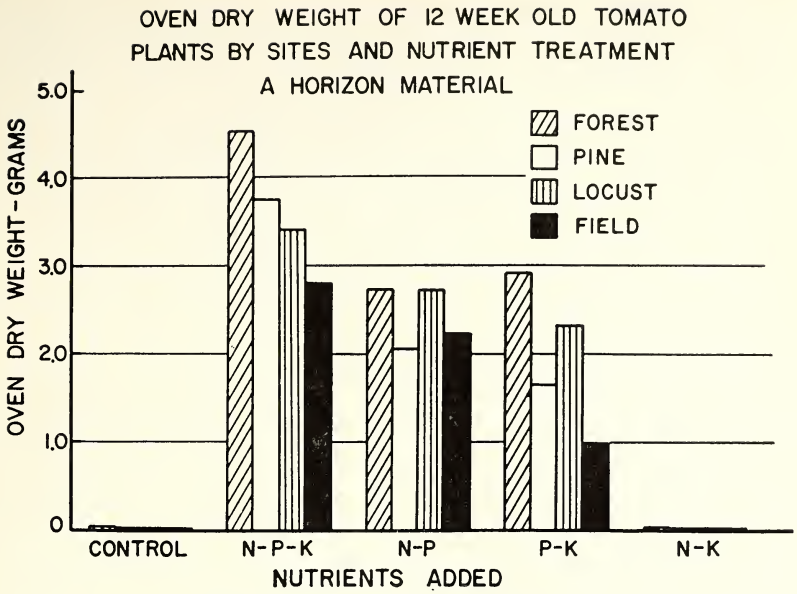

Figure 1b. Tomato on A-horizon soil.

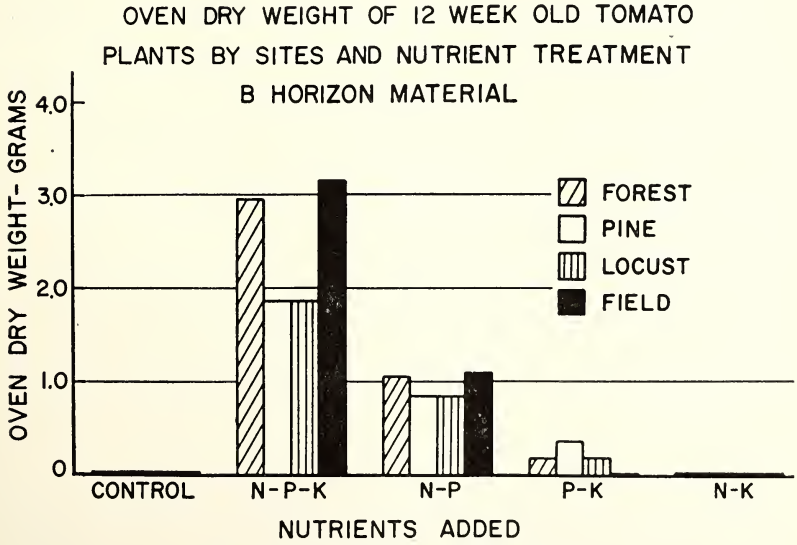

Figure 1c. Tomato on B-horizon soil.

fields where erosion has been severe and trees are planted directly on B-horizon soil, heavier applications of nitrogen and potassium may be necessary.

In an earlier study on the same sites, growth of yellow-poplar seedlings was correlated with pore volume, bulk density, and organic content of the soil for all except the locust site. The physical properties of soil from the locust site appeared unfavorable for seedling growth, and available phosphorus was only slightly higher than on the other sites. In spite of these conditions, yellow-poplar seedlings grew almost as much as on a natural forest soil. The present study shows that available phosphorus was lacking in all four soils investigated and does not explain the relatively good growth of yellow-poplar seedlings on the soil from the black locust site. It appears clear, however, that fertilization, especially with phosphorus, can be expected to benefit the establishment of hardwood stands on sites similar to the ones studied.

Conclusion

This study shows that available phosphorus may be one factor limiting the growth of planted hardwoods on abandoned old fields in southern Indiana. After phosphorus is applied, nitrogen then potassium appear to be limiting factors. Nitrogen and potassium deficiencies are more critical on B-horizon soil than on A-horizon soil. Chemical as well as physical soil factors must be considered in evaluating old field sites for survival and growth of hardwoods with high site requirements. In future tree planting research on old fields the application of fertilizer, especially phosphorus, should be evaluated.

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ZOOLOGY

Chairman: WILLIAM EBERLY, Manchester College
ROBERT COOPER, Ball State College, was elected chairman for 1964

Assay of Chicken Pituitary Glands by Means of Radioactive Phosphorus[1]

FRANK J. ZELLER, Indiana University

It is often of interest to determine the gonadotropin content of the anterior pituitary gland under normal and experimental conditions by means of a biological assay. The newly-hatched cockerel has been the assay animal of choice in our laboratory. Breneman *et al.*, (2) observed that weight changes in the testes of the cockerels after gonadotropin stimulation served as an excellent end-point. More recently a new end-point, the uptake of radioactive phosphorus (P^{32}) by the testes, has been shown by Breneman *et al.* (3) to be sensitive to small amounts of purified samples of FSH, LH, and whole pituitary glands. This paper presents some further studies on whole pituitary material using the P^{32} assay.

Materials and Methods

The experimental animals used in these investigations were Single-Comb White Leghorn chickens. The assay birds were received from the hatchery when one day old, were injected on day two, and autopsied when three days old. They received no food or water. The "donor" birds were killed at appropriate times and their anterior pituitary glands removed, weighed, and stored in acetone until they were assayed for their gonadotropin content. At assay time, the pituitary glands were air dried, ground, and diluted with distilled water to the desired concentration. This pituitary material was then injected in two equal doses into the cockerels 24 and 12 hours before the scheduled autopsy time. Three microcuries of P^{32} were administered to each assay bird 18 hours before autopsy time. At autopsy, the testes were removed, cleaned, weighed, and each pair was placed on a separate planchet. The testes were allowed to air dry for 48 hours and then were counted in a Baird-Atomic general purpose multiscaler. The end-point was the counts per minute per milligram of wet testes tissue. There were 12-20 birds in each assay series.

Results

One study was directed at determining the levels of gonadotropic material present in normal male chickens and capons over a period of time from the age of 20 to 207 days. Caponizations were performed when the birds were 3-5 days old. Table I compares the pituitary weights of the two groups of birds. The capon anterior pituitary glands were always heavier than the control glands.

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1. Contribution No. 744 from the Zoology Department, Indiana University.

TABLE I. Anterior Pituitary Gland Weights

Age Days	Average Weight, mgs. Controls	Capons
20	1.88	2.02
40	4.48	6.23
60	5.83	10.28
80	8.03	13.50
102	8.55	14.70
123	8.78	19.40
146	9.40	17.90
175	9.30	22.54
207	11.62	19.74

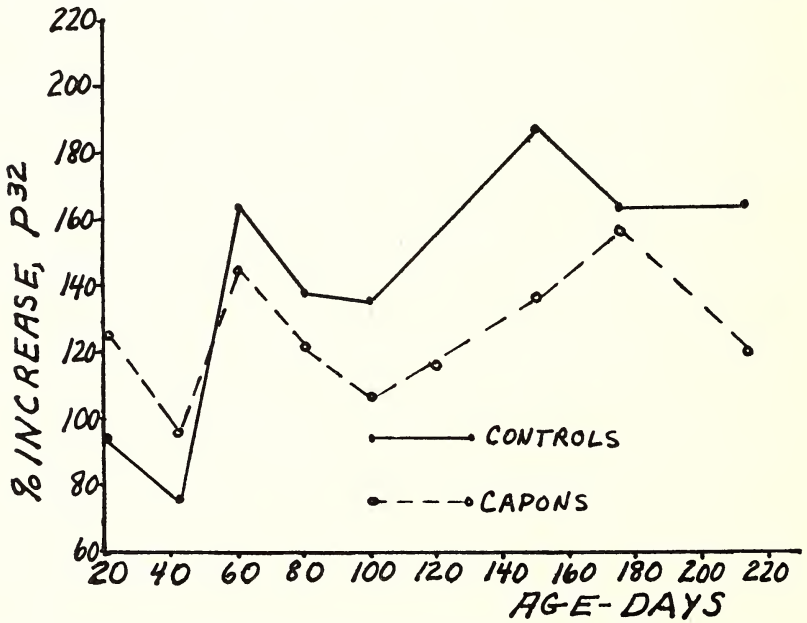

Figure 1. Gonadotropic Content of Normal Male Birds and Capons.

Figure 1 records the changes in gonadotropin content over the 200 day period. Each point on the graph represents a series of assay birds in which each bird received 1.0 mg. of donor pituitary gland. The basis of comparison of the different groups was the per-cent increase of P^{32} obtained by each series of birds over the control series for that particular assay. The capon pituitary glands at 40 days of age contained more gonadotropin than did the control glands. This is in agreement with results of Breneman and Mason (1). After 40 days, the control glands contained more gonadotropin per unit pituitary weight than did

the capons. This was also reported by Herrick *et al.* (4) using testes weights.

Other experiments were performed to note the effects of sex hormones on the gonadotropic content of capon pituitary glands and to further test the sensitivity of the P^{32} assay. Figure 2 illustrates the effects of repeated doses of 75 μgm. estradiol[2] on 50 and 75 day old

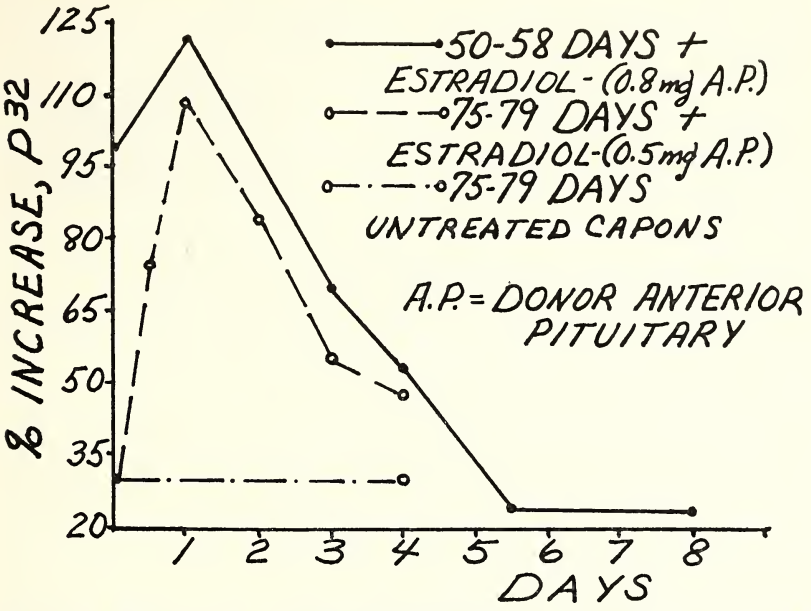

Figure 2. Effect of 75μgm. Estradiol dipropionate on the Gonadotropic Content of 50-58 and 75-79 Day Old Capons.

capons. In both cases there was an initial increase in gonadotropic content after one injection followed by a steady decrease with subsequent injections of the hormone. The assay was sensitive to changes within 12 hours after the first injection.

Figure 3 records the results obtained when 100 μgm. testosterone propionate[3] were administered to 52 day old capons. A gonadotropin increase was noted within 12 hours after the first injection. This was maintained until after the third injection when the content showed a further increase. Also to be observed in Figure 3 are the results obtained from administering 75 μgm. estradiol and 100 μgm. testosterone together to 68 day old capons. The curve is similar to the one obtained from administering testosterone alone.

2. Estradiol dipropionate courtesy of Dr. A. A. Renzi, CIBA Pharmaceuticals, Inc.

3. Testosterone propionate courtesy of Dr. J. C. Siegrist, Schering Corporation.

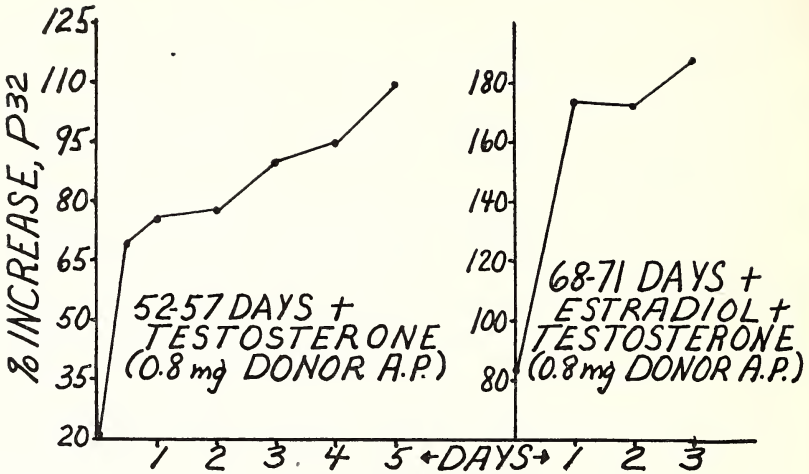

Figure 3. A. Effect of 100 μgm. Testosterone on the Gonadotropic Content of 52-57 Day Old Capons. B. Effect of 100 μgm. Testosterone + 75 μgm. Estradiol on the Gonadotropic Content of 68-71 Day Old Capons.

Summary

Although not specific for a particular gonadotropin, the method described in this paper utilizing the P^{32} uptake by the testes of newly-hatched cockerels is a sensitive assay and one that can be of use in determining the total gonadotropin content of pituitary glands under normal and experimental conditions.

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Oxygen Uptake in Heat-Stressed Chick Embryos

W. C. Gunther, Valparaiso University

Introduction

The uptake of oxygen by the chick embryo has been extensively investigated by various workers. A review is given by Taylor (12). More recently, attention has been centered on the oxygen consumption of the embryo by whole egg techniques, measured in a modified Warburg as described by Csabay, et al. (1). Considerable research has also developed around the problem of separating respiring membranes (yolk sac, allantois, amnion) from the embryo and measuring the oxygen uptake of each (8, 9).

Gunther (2, 3) has reported various behaviorial anomalies and biochemical aberrations in chicks hatched from eggs subjected to non-optimally high temperatures during the first five days of incubation. Inasmuch as the results of some of these investigations indicated perhaps an involvement of oxygen, Warburg manometric pilot studies on the oxygen consumption of such heat-stressed embryos were initiated. The oxygen uptake of these embryos is compared with that of control embryos incubated at normal temperature, and the significance of the mean differences is evaluated by statistical methods.

Materials and Methods

One thousand eighty chick eggs (White Rock) were incubated for varying numbers of hours from July 23 through August 22. The eggs were placed in the incubators for periods ranging from 64 to 149 hours in lots of 72 at weekly intervals. Forty-eight eggs from each lot were incubated at 41° C. (called experimentals) and 24 were placed in the optimal temperature incubator, set at 37.5° C. (called controls). At the appropriate time the embryos were removed from the eggs and, after all membranes had been trimmed, were weighed to the nearest milligram. In the manometers only those embryos were used which showed strong heart beats and maximum development. While it was impossible with the techniques employed to trim each embryo exactly alike, the average weights agreed rather well with other series of weighed embryos (unpublished data).

For each particular age group (in hours) during the periods July 23 to July 25 and August 1 to August 8, three experimentals and 3 controls were placed one in each of 6 reaction vessels. The reaction vessels contained 10 ml. Spratt's (11) chick Ringer (without agar, for which the term maintenance medium appears appropriate) with 0.2 ml. potassium hydroxide in the center well. The vessels containing the embryos were attached to manometers and placed on a Bronwell Warburg with the bath water at 37.5° C. A seventh reaction vessel (con-

1. Supported by research grant HD 00202-04S1 National Institute of Child Health and Human Development, United States Public Health Service, and by a summer research grant from Valparaiso University.

taining only water) was attached to a seventh manometer, serving as a thermobarometer. The shaking frequency of the Warburg was reduced to 60 per minute by means of a special pulley. This slower speed was found desirable in order to keep the embryos intact.

For the period August 20 to August 22, two more reaction vessels and manometers were added, so that four experimental and four control embryos were run at the same time.

The manometers were read at 15-minute intervals over a two-hour period. The individual readings were converted to microliters of oxygen consumed by the whole embryo, and to microliters of oxygen consumed per milligram of wet weight of each embryo. The results are expressed both as the average microliters of oxygen consumed per hour per 3 (or 4) embryos without regard to weight (total oxygen consumed) and as the average microliters of oxygen consumed per hour per milligram wet weight per 3 (or 4) embryos.

For the period August 20 to August 22, the experimental set-up was identical with the above. However, 5 grams of sucrose were added to each liter of Spratt's Ringer solution.

Results

The results are summarized in table 1. Student's "t-tests" were

TABLE 1. Summary of O_2 consumption.

Age	ul 0_2 uptake per hr. Control	Experimental	Significance (df = 5)	ul 0_2 uptake per hr. per mg. wet weight Control	Experimental	Significance (df = 5)
Maintenance medium (Spratt's)						
July 23—July 25						
100hr.	25.640	22.981	none	.266	.262	none
125hr.	50.831	45.201	none	.252	.206	none
149hr.	70.075	65.283	none	.158	.133	none
August 1—August 2						
78hr.	9.376	14.781	P=<.05	.667	.422	none
98hr.	17.941	29.345	P=<.05	.261	.260	none
August 5—August 8						
64hr.	8.892	10.263	none	.735	.650	none
88hr.	11.513	17.031	none	.467	.463	none
112hr.	39.000	43.203	none	.303	.250	P=<.05
136hr.	56.160	63.729	none	.200	.144	P=<.05
Sucrose medium (Spratt's)						
August 20—August 22						
68hr.	14.256	12.037	none (df=7)	.758	.975	none (df=7)
87hr.	10.556	11.213	none (df=7)	.258	.270	none (df=7)
112hr.	22.456	23.675	none (df=7)	.235	.355	none (df=7)

made to test the significance of the mean differences of oxygen uptake between each lot of control and experimental embryos as indicated. Error variances were tested by the "F-max" procedure and were found to be homogeneous. It is seen that with increasing age both control and experimental chick embryos require an ever-increasing amount of oxygen when cultured on the maintenance medium (Spratt's Ringer without sucrose and agar). When sucrose is added to this medium, both controls and experimentals show a slight initial decline in oxygen consumption, followed by a rapid rise.

On the maintenance medium, three lots of experimentals (July 23-25) consistently consumed less oxygen than did the controls, but the mean difference failed to attain statistical significance. At all other periods the experimentals consumed more oxygen than the controls, and for the period August 1-2 the difference in the means between the two groups attained significance ($P<.05$). With sucrose added to the medium the means between the two groups failed to attain significance at any time. Of interest in this latter group, however, is the fact that the 68-hour experimental embryos consumed less oxygen than did the controls, but the 87-hour and the 112-hour experimentals used more oxygen than did the controls.

When the microliters of oxygen consumed are calculated on the basis of milligrams wet weight per hour per 3 (or 4) embryos for each group, it is evident that on the maintenance medium all age lots in both groups (controls and experimentals) consume less oxygen with increasing age. In addition, experimental embryos indicate an uptake of oxygen which is less than the controls at all ages. The difference in the means in one group (August 5-8) attained significance with 112-hour and 136-hour embryos, the experimentals consuming less oxygen.

If sucrose is added to the medium, the average microliters of oxygen uptake per hour per milligram wet weight of 4 experimental embryos is higher than that of 4 control embryos at all ages. On this medium both the 87-hour controls and experimentals consume less oxygen than the 68-hour lot. However, the 112-hour experimentals reverse the downward trend in oxygen consumption. On the other hand, the controls continue to consume less oxygen at increased age levels.

Discussion

The fact of increased oxygen consumption of chick embryos with increasing age has been firmly established in the literature (1, 10, 12). Romanoff (10) has also found that the amount of oxygen consumed per hour per unit (gram) of body weight declines to a minimum at the day before hatching. The research reported herein appears to be in general agreement with these findings. No attempt has been made to compare absolute values with those reported in the literature. In the first place the methods used by other workers are so varied, with the results expressed in such a variety of ways, that it would be meaningless to make comparisons at the present time. Furthermore, of more importance to the overall relation of embryonic nonoptimally high temperature stress to what I hesitatingly call mental retardation in these chicks is the difference in oxygen consumption between the controls and experimentals.

By way of explanation it should be stated that whenever I undertake embryonic physiological study under these conditions, I permit the majority of the eggs from the same batch to hatch. This is done in order to establish that behavior and/or biochemical differences between control and experimental chicks do exist. Thus far, all evidence gained from these studies points to a definite positive relationship between the degree of temperature insult coupled with the length of such stress, and the behavior, weight, and certain physical and biochemical aberrations of the hatched birds (4, 5, 6, 7).

The differences in the oxygen uptake between the control and experimental embryos as reported above indicate at least tentatively that the metabolic rate of the experimentals has been disturbed by the heat treatment. The differences in the means were statistically significant among two lots (August 1-2) without regard to weight. When expressed as microliters of oxygen consumed per hour per milligram wet weight of the embryo the means were likewise significantly different among two other lots (August 5-8). In the former case the metabolic rate between controls and experimentals expressed as microliters of oxygen uptake per milligram wet weight, although clearly lower for the experimentals, was not significantly different. In the latter case the oxygen consumption without regard to embryonic weight was higher in the case of the experimentals. Were it not for the fact that in three lots (July 23-25) the experimentals consumed less oxygen than did the controls, it would be tempting to theorize that these data all indicate a more rapid development of the embryo undergoing heat treatment. In other words, if the experimental embryos are developmentally older than the controls, one would expect to find a higher oxygen consumption over the controls without regard to body weight, and a lower oxygen consumption when these results are expressed as microliters per unit of body weight. However, in view of the conflicting nature of these data, it would be premature to accept this explanation without reservation. Data for more embryos per lot should be obtained, with oxygen consumption determinations being made from the same batch of eggs over longer periods of time at shorter intervals. Refinements of technique, particularly with regard to trimming the membranes and weighing the embryos, should be introduced. Such work is presently being continued in our laboratory.

When sucrose is added to the maintenance medium, the metabolic rate is apparently even more disturbed and interpretation of the data becomes increasingly difficult. Contrary to expectations based on developmental rather than chronological age, the 68-hour heat-treated embryos consumed less oxygen than did the controls. However, in the 87-hour and 112-hour heat-stressed embryos the oxygen uptake was greater, as could be expected. Puzzling is the fact that both the controls and experimentals in the 87-hour lot consumed less oxygen than did those of the 68-hour lot.

When the metabolic rate is expressed per unit of body weight for the same embryos cultured on the sucrose medium, all experimentals consumed more oxygen than did the controls. If the experimentals were developmentally older by reason of accelerated growth because of the nonoptimally high temperature, they should consume less oxygen than

the controls. The experimentals may be farther along in development, but may not be able to make as effective use of nutrients as do the controls. Clearly, here also the oxygen uptake of more embryos from the same batch over longer periods of time at closer intervals should be determined. It might be interesting to use several different sugars (including those which the normal chick embryo cannot metabolize) in an effort to determine whether there is some difference in the ability of the heat-stressed animals to make effective use of these. Our investigation continues along these lines, also.

Summary

The oxygen uptake of chick embryos from different hatches subjected for varying numbers of hours to the optimal temperature of 37.5° C. was compared with that of embryos from the same hatches treated for similar periods but incubated at the nonoptimally high temperature of 41° C. Determination of oxygen consumption was made by the standard Warburg technique, and expressed as average microliters consumed per hour per embryo without regard to weight, and as average microliters per hour per embryo per milligram wet weight.

With increasing age and on a maintenance medium both control and experimental embryos consume an ever-increasing amount of oxygen. When these results are expressed in terms of microliters of oxygen consumed per hour per embryo per milligram wet weight, the oxygen consumption declines with inceasing age.

Statistically significant differences in oxygen consumption were recorded between control and heat-stressed embryos among 4 age groups. At ages other than these, differences were noted, but these failed to attain statistical significance.

When sucrose was added to the maintenance medium, differences in oxygen consumption among three lots were again noted, but these failed to attain significance. Of particular interest was the fact that the difference between control and experimental embryos in the amount of oxygen consumed in the sucrose medium was of a different order than those differences noted between controls and experimental embryos in the maintenance medium.

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Further Notes on the Occurrence of the Whistling Swan *(Cygnus columbianus L.)* in Delaware County, Indiana

Robert H. Cooper, Ball State Teachers College

Since the report of October, 1962, to the Zoology Section of the Indiana Academy of Science was made a committee appointed by the Muncie Park Board has carried out plans for establishing a Delaware County Wildlife Refuge. This committee was promised that protection would be given up until May 15, 1963, for the north-east wing of the Prairie Creek Reservoir on which the twenty whistling swans lived for three weeks during March of 1962. Protection is again to be given from September 15, 1963, until May 15, 1964. It was not known at that time what this planning would result in so far as the migrating swans was concerned. The committee, consisting of a number of interested men and women in Delaware County, put up five signs—the upper part giving the name of the area to be permanent and the lower part giving the restrictions for the area to be removed during the summer season—May 15 to September 15. Recommended seeds and plants were purchased for the refuge but could not be used because of regulations set up by the Water Company, owner of the reservoir.

After the signs began going up, it was learned that there was energetic opposition concerning the fact that boats would not be allowed on the east arm of the large reservoir from September 15 to May 15, fishing would not be permitted at that time and persons would not be allowed to tie boats to the shore line.

Some science workers and others watched the reservoir closely during the month of March, 1963. On Monday, March 18, ten swans had landed in almost the identical spot where the twenty swans were located last year. Five were immature and five were adults. The weather was very severe and the wind was high. The swans seemed to enjoy it and were observed feeding and flapping their wings into the cold, strong wind. On Wednesday, March 20, the ten swans were gone and no others came during the Spring of 1963.

It was learned rather authentically that certain persons took a boat into the area and that noises were made in order to frighten the swans away. A few of the land owners and promoters have been disturbed about the area being a reserve, and some members of the committee were informed that procedures had been used to see that the swans did not stay in the area. During the summer of 1963 special privileges were granted a few parties to tie up at locations on the banks of the east wing. It is hoped that this condition will be corrected.

Letters were secured from Dr. Arthur A. Allen of Cornell University and from other scientific authorities in order to give reliable publicity and encouragement for maintaining this area where the whistling swans seem to want to stop and feed. The natural food supply and other natural ecological conditions seem to be very suitable for the swans in migration.

Movements of *Myotis lucifugus lucifugus* from a Colony in Boone County, Indiana

Stephen Humphrey and James B. Cope, Earlham College

Nine trips have been made since 1958 to a colony of little brown bats (*Myotis lucifugus lucifugus* LeConte) at Thorntown, in Boone County, Indiana, for the purpose of banding and recovering previously banded bats. The dates of banding are as follows: August 9, 1959, August 19, 1959, August 20, 1960, August 3, 1961, July 31, 1962, June 5, 1963, August 14, 1963, September 29, 1963, and October 10, 1963. In these six years, 2410 bats were handled, an average of 400 individuals per year; of the 1710 bats which were banded, 313 were recaptured at Thorntown. This work has been done in conjunction with a banding project throughout Indiana and parts of Kentucky. Acknowledgement is made to many students of Earlham College for their time spent in this study; to National Science Foundation Grant G-5571 which financed in part this study, and particularly to Roy Randel for his generous and continuous cooperation in allowing us to study the colony in one of the buildings on his farm. We are indebted to Gertrude L. Ward for the preparation of the map.

It is well known that *Myotis lucifugus* migrates (2, 4). They go north in the spring and when they arrive at their destinations, the females form a coloney and bear one young each. The males do not colonize with the females and young, but are thought to form stag colonies or move erratically within a large area (1). In the fall, the bats migrate south to hibernate in caves.

Of the bats banded at Thorntown in six years, 47 were recaptured at other places. Thirteen recoveries were made in Grotto Cave and eight in Coon's Cave, both in Monroe County about 70 miles south of Thorntown. There was one recovery in each of several other caves in this area, including Ray's Cave, Salamander Cave, and Buckner's Cave. In Lawrence County, three Thorntown bats were recaptured at Donnehue's Cave, 88 miles south of the nursing colony; farther south in Lawrence County, three Thorntown bats were taken at Tunnelton, which is another nursery colony, and two at Donaldson's Cave. Seven bats were recovered in Wyandotte Cave, Crawford County, 132 miles south of Thorntown. Three bats were recovered in Wind Cave, Breckinridge County, Kentucky, 165 miles south of Thorntown. The most distant records are of two bats recaptured in Colossal Cave, Edmonson County, Kentucky, 200 miles from the summer colony.

Thus from Thorntown south, the migrating bats follow a fairly narrow route along the line of caves in which they roost or winter. As one might expect, this route corresponds with the belt of Mississippian limestone in which the caves are formed, Fig. 1. However, there is some evidence that this cave belt migration route is not closely followed. Three bats were captured during the time of fall migration well east of the cave belt, one at Shirley, in Henry County, one at Franklin, Johnson

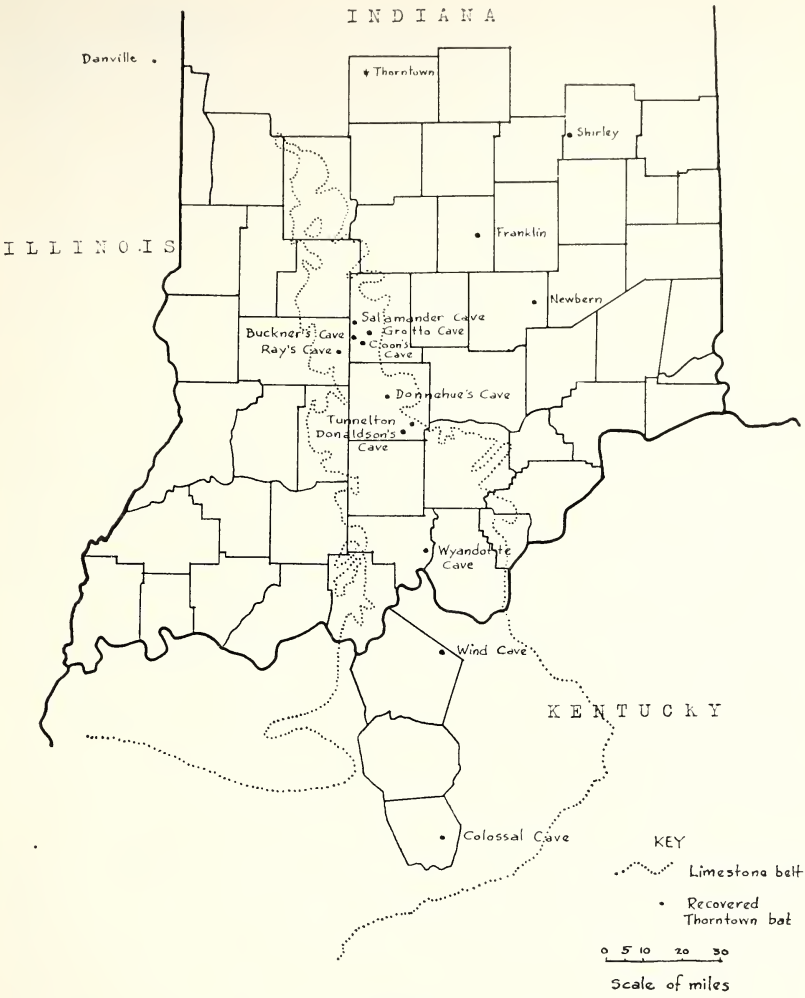

Figure 1

County, and one at Newbern, Bartholomew County. One bat turned up about 70 miles west of Thorntown during fall migration, at Danville, Vermillion County, Illinois. It seems evident that there is some sporadic movement that is not explained by north-south migration.

The data which pinpoint migration routes also help in establishing the dates of migration. As late as August 19, 1959, and August 20, 1960, there were respectively 485 and 450 *M. lucifugus* at the colony, about the same number as on August 3, 1961 and August 9, 1958, earlier in the month. Thus it appears that during the third week of August most of the nursery population is still present. The following data shed light on the dates of southward movement:

Bats banded at Thorntown	Recaptures: place and date	Sex	Number of days to migrate	Distance in miles
1. July 31, 1962	Wyandotte Cave September 5, 1962	F	36	132
2. August 3, 1961	Wyandotte Cave September 6, 1961	M	32	132
3. August 3, 1961	Wyandotte Cave August 23, 1961	M	20	132
4. August 20, 1960	Donnehue's Cave September 2, 1960	M	13	88
5. August 20, 1960	Donnehue's Cave September 1, 1960	M	12	88

From these data, which cover through 1962, it seems that the southward migration takes place during the month of August, probably during the last two weeks of August and the first week of September. On August 14, 1963, there was an estimated total population of 450 bats at Thorntown. On September 29, 1963, there were about 32 bats present, well after our supposed dates of migration; on October 10, 1963, there were still three bats at the colony. This leads us to believe that the peak of southward migration is in late August, but that some bats stay on, resulting in a slowly diminishing population at the end of the season.

Dates of spring migration are not so well defined. Of the bats that were taken at a point south of Thorntown in the spring and again later that year at Thorntown, most were from Coon's Cave, Grotto Cave and Wyandotte. The banding at Coon's Cave was on March 28, 1961, and there was no migratory activity at that time. At Grotto Cave on April 21, 1961, the bats were active; there was one previously banded Thorntown bat there, but it could have been hibernating as well as migrating. A more interesting record is that of a migrating female banded at Wyandotte on April 20, 1963, and recaptured at Thorntown on June 5, 1963. It appears from this that spring migration occurs during the last two weeks of April, during May and probably during the first week of June.

When the colony was visited on June 5, 1963, there was an estimated total population of 135 bats, and no young had been born. Our previous population figures of four and five hundred included offspring. Therefore, if we follow Griffin (3) who found only an occasional male in the nursery colony, and this corroborates our own findings of 98 to 100 percent females rather than those of Cagle and Cockrum (1) who found 38 percent adult males as late as the first week in June, we can assume the population had not built up to its peak. Thus, migration was going on after June 5. On August 14 the estimated total population was the expected 400-450 which seemed to be consistent with the preceding year's population at that time of year.

It is interesting to note whether or not individual bats are consistent in visiting the colony each summer. Of the 1710 bats banded at Thorntown through September 29, 1963, 243 were captured there two different times, 54 were captured there three times, 11 were captured there four times, four were captured five times, and one, six times. Most of these captures were in consecutive years. These recaptures, however, are only 18 percent of the bats banded. There is some inefficiency in banding, but usually about 65 percent of the population is captured. Probably deaths are partly to blame for the low number of returns. Gifford and Griffin (2) noted that bats move to different nursery colonies; while we have no information to substantiate this for the Thorntown colony, it is conceivable that this could be a factor in the low percent of returns.

There is a definite difference in the rate of occurrence of the sexes at the colony. Of the 243 bats that were captured twice, 81 percent were females. Of the 54 bats captured three times, 78 percent were females. Of the bats captured more than three times, 100 percent were females. This substantiates the observation that most males of the species spend their summers apart from the nursery colony. One male was banded at a nursery colony at Tunnelton, Ind., on August 8, 1958, and recaptured at Thorntown on August 9, 1959. This bat was about 90 miles farther north in 1959 that it was at the same date in 1958.

An interesting proportion of sexes was noted on September 29, 1963. Of the 11 bats already banded at the time, nine were females, corresponding with the proportions noted in the nursery population. As we would expect, seven of the nine recaptured females had been at the colony earlier in the summer, and one of the two recaptured males had also been present. Of the 17 bats that had not been banded, 11 were males; this proportion indicates that most of these 17 were ones which had only recently moved in, perhaps during migration.

Although much of our evidence is inconclusive, it shows many trends in the bats' movements. With this as a beginning, we may be able to trace patterns of bat activity in a very significant way. Therefore, while the colony is preserved, we shall have an excellent opportunity for further study.

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The Effect of Chlorpromazine on the Learning Process

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Introduction

The tranquilizer chlorpromazine apparently affects the brain by inhibiting the activities of the hypothalamus. When an animal is threatened or under stress, it responds with a number of physiological changes triggered by mechanisms within the hypothalamus, particularly in its posterior section. In this portion of the brain are centers which play an important role in the animal's automatic protective behavior. In the rear section is a system which controls emergency responses that prepare the animal for fight or flight.

When stimulated properly, nerve impulses are transmitted from the site of stimulation to the thalamus by means of pathways called lemnisci. From there the impulses are relayed to a section of the cerebral cortex which interprets the sensation. Parallel to the lemnisci is a system known as the activating system; located in the central core of the brain, it collects some of the impulses passing through the lemnisci and carries them directly to the midbrain reticular formation behind the hypothalamus. The reticular formation then in turn relays the impulses to the hypothalamus. From there, as when from the lemnisci, the impulses are sent to the cerebral cortex by way of the diffuse projection system. When stimulated, the activating system produces an arousal reaction. Work by Himwick (4) shows chlorpromazine in small doses blocks this reaction. Using an electroencephalogram it is possible to show a painful stimulus normally produces a great brain wave change which is indicative of arousal reaction; but while under the influence of chlorpromazine, no such brain wave change is produced upon administration of a painful stimulus. The impulses appear slowed and to some degree halted by the action of a tranquilizer, not passing above the hypothalamus into the cerebral cortex for interpretation.

DeRopp (1) and Southwick (5) agree that in substantial doses chlorpromazine may produce large reductions in blood pressures, tremors, gastric disturbances, skin eruptions, and possibly jaundice. It typically reduces basal metabolism and quiets agitated emotions.

According to Lashley (3), experiments with rats wherein lesions to the cerebral cortex involved an average of 28.4 per cent of area, indicated that the cerebral destruction produced no significant effect upon the learning ability of a particular habit.

At the present time there is conflicting evidence as to whether tranquilizers produce or induce an ill effect on the cerebral cortex or any brain area during the process of stimuli transportation and interpretation. This research was conducted to determine the effect of chlorpromazine on the learning process in white rats.

Methods

Two sets of trials were run, using different rats in the separate sets. In the first set of trials, shock avoidance was used in testing. A

modified Skinner box, or problem box, was separated in the center by a partition, making a square on each side of the partition with linear dimensions of 7″ x 7″, the entire base of which was a grid conducting the shock impulses. Two holes 2″ x 2″, separated from one another by 2½″, were cut in the partition, and one was marked in black for visual identification. Since one side of the Skinner box was of clear plastic and the other of opaque fiberboard, the sides were reversed for some of the trials, with no significant change in the rat's preference for the marked door. Four rats were used, two for controls and two as experi-

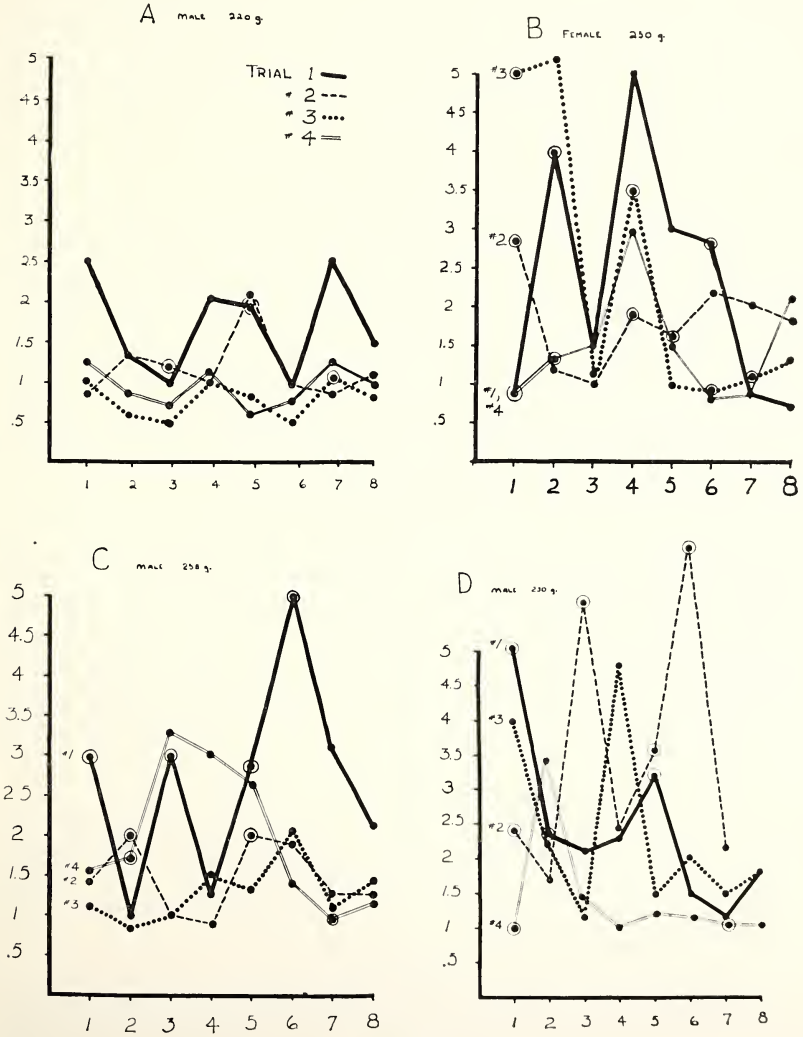

Figure 1.

mentals. The experimentals were chosen on the basis of earlier trials without the tranquilizer. For the experimentals, chlorpromazine was injected intraperitoneally approximately fifteen minutes before testing began. The tranquilizer was administered to the rats in the amount of .25 cc/50g. body weight. Fifteen minutes later, a rat was placed on one side of the partition facing away from the two holes. The shock and a timer were turned on simultaneously. If the rat passed through the marked hole, it was counted as a positive reaction and the shock was turned off immediately. If he passed through the unmarked hole, the reaction was counted as negative, and, while the time was turned off when the rat passed through the hole, the shock was left on for an additional two seconds. The same method was used on the controls with no tranquilizer. The times were entered to the nearest tenth of a second, with an indication of which were positive and which were negative. On the days of testing, a minimum of two trials per rat per day were run, with six to eight repetitions each trial.

Results

The results of the first set of experiments are shown in Figure 1. Rats A and B are the controls, and rats C and D the experimentals. Each circle around a particular time identifies a negative trial. The capriciousness of the only female rat tested may have been due partially to her pregnant condition. The extreme erratic behavior in the first two trials of rat D is noteworthy. Rat D was, when not under the influence of the tranquilizer, of very ill temper. In comparing the trials of individual rats against each other, the learning which occurred is apparent. Although not all of the rats showed progress as steady as rat A's, they appeared to be showing definite preference toward the correct hole. There is also an improvement in times as well.

Methods

In the second set of trials a runway was used in testing four female and three male rats who were on a twenty-three hour starvation diet. The runway was three feet long with a goal box at each end. The tranquilizer was administered as in the other trial. Each rat was placed in the end box without food with the door closed. A stop watch was started as the door was opened and stopped when the rat got all four feet into the goal box at the other end which contained some pellets of food.

Results

The results of the runway experiment are shown in Figure 2. Rats A, B, C, and D were the females; E, F, and G the males. The first nine trials were without the tranquilizer and the last five were with the tranquilizer. In all but G, the times of the tranquilized trials were slower than the control trials.

Discussion

For comparison between the controls and experimentals in the first set of trials, use of rats A and C would be best. While rat C took longer to adjust to the situation, his times dropped, especially in trial three,

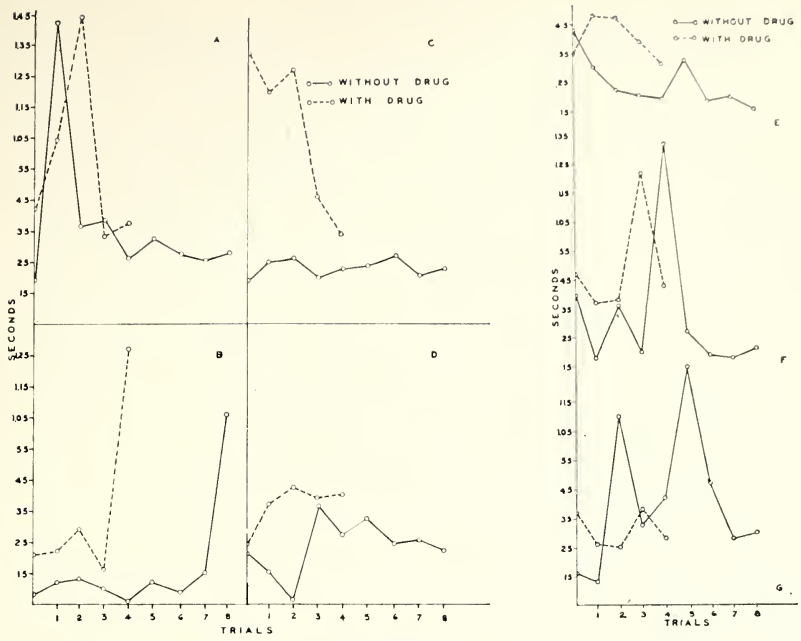

Figure 2

nearly to the level of rat A's. The inconsistency in rats B and D may have been due to the condition of B and the disposition of D.

Miller from Garattini (2), feels shock avoidance is the best method of testing because the apathetic conditions produced by a tranquilizer rule out the use of such drives as hunger and thirst. Electric shock can be used for motivation in almost any type of behavior. However, any emotional disturbance produced by the shock becomes an unwanted variable. In this experiment it became evident that it was easy to intensify the shock beyond that point which was safe and workable in rats, especially with the comparatively slowed reactions of the tranquilized rats. In reference to the second set of trials, the rats showed a fear of the device used for testing. Under the effects of the tranquilizer this fear was not so apparent. After the injection of the tranquilizer, the food consumption dropped in the experimentals. Their intake of water during the next twenty-three hours was also reduced.

Of the two sets of trials those using the Skinner box were more effective. The tests using the runway and the same rats for tests with and without the tranquilizer merely would test retention of the problem and not learning of a new situation.

It is difficult to determine whether the learning which was apparent in both experimentals and controls but definitely retarded in the experimentals was slowed because of a hindrance to the learning process or because of the relaxant and apathetic effects produced by chlorpromazine.

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